REPORT

PHASE II MOIRA RIVER STUDY
IMPACTS OF THE FORMER DELORO MINE SITE ON THE MOIRA RIVER SYSTEM

January 2001

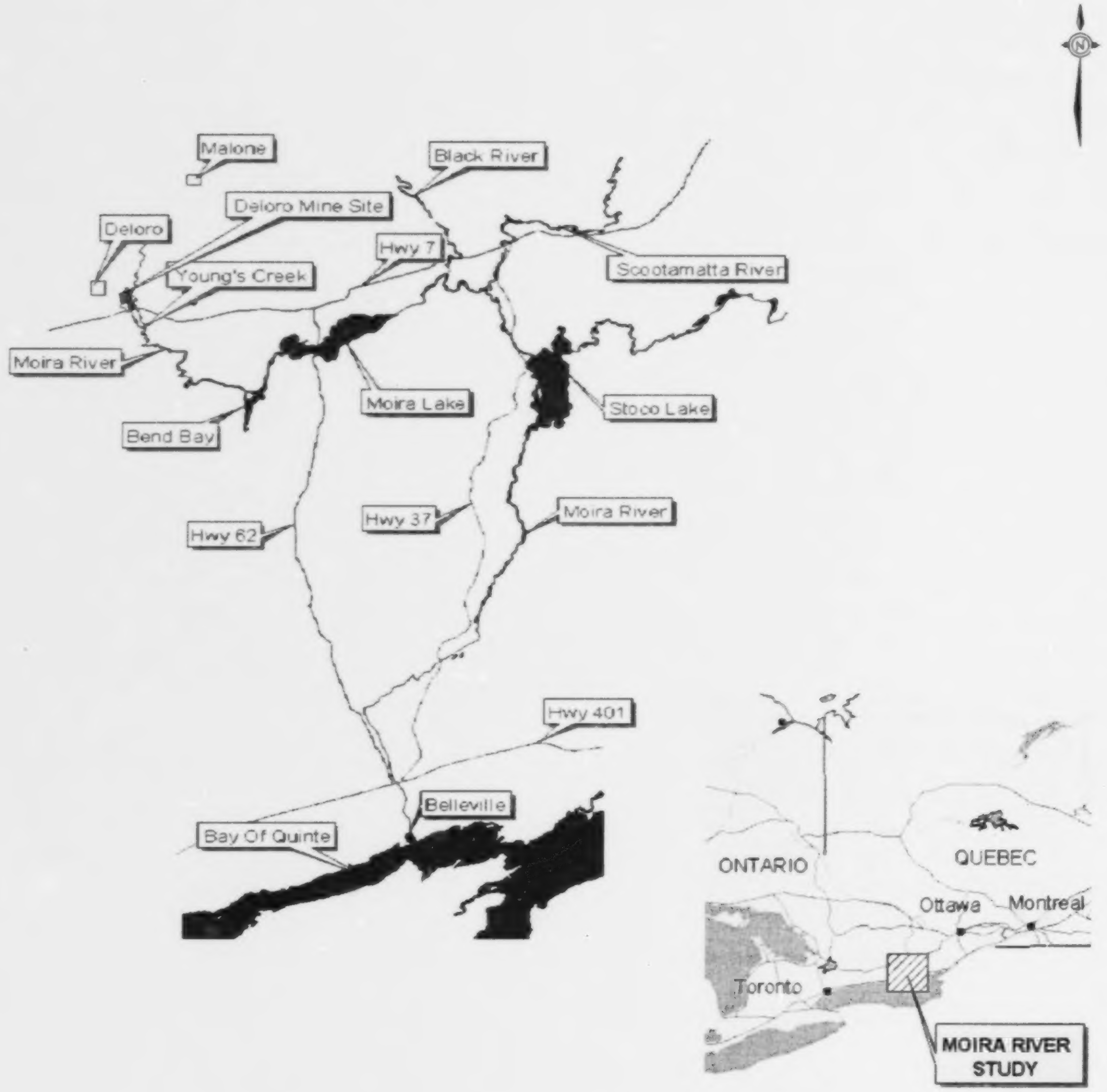
1. INTRODUCTION

1.1 Background

The Moira River is located in southern Ontario and flows from the Canadian Shield south across the St. Lawrence lowlands to Belleville and the Bay of Quinte on Lake Ontario. The Deloro Mine Site is located on this river about 45 kilometres north of Belleville, Ontario (Figure 1.1-1). Gold mining started in the late 1860s. By the early 1900s, the gold mines had closed and the Deloro Mine Site was used to process silver and cobalt ores from other mines in northern Ontario. From the 1930s to the 1950s, smelted ore was brought from Eldorado Nuclear Limited in Port Hope for further refinement to extract cobalt. The Deloro Mine Site was the first plant in the world to produce cobalt commercially and was also a leading producer of stellite, a cobalt-chromium-tungsten alloy highly valued during the war years. Ores from all over the world were processed in Deloro's smelters. Pesticides were produced from the arsenic by-products of the smelting operations and manufactured as a major activity at the Deloro Mine Site until those products were replaced by organic pesticides in the late 1950s.

By the time all operations ceased, a wide variety of waste materials containing arsenic and a variety of other metals had accumulated and affected the quality of water and soils on the Deloro Mine Site, as well as quality of water and sediment in the Moira River system. When the last owners abandoned the property in 1979, the Ministry of the Environment (MOE) assumed responsibility for the environmental management of the Deloro Mine Site as 'remediator of last resort'.

Since then, the ministry has made significant reductions in the contribution of metals to the Moira River system through a number of remedial actions. Eight hectares of tailings were covered, unsafe buildings demolished and mine shafts were located and sealed. The ministry also built and continues to pay for the operation of a treatment plant that removes arsenic and other heavy metals from the groundwater on the Deloro Mine Site. As a result of these actions, the ministry has reported that loadings of arsenic to the Moira River have been reduced by more than 80 per cent. The ministry's consultants are currently working on a plan for the final cleanup of the Deloro Mine Site, to control and securely contain all types of contamination at the Deloro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Scootamatta River
Moira River
Moira Lake
Stoco Lake
Bend Bay
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Hwy 37
Moira River
Hwy 401
Belleville
Bay Of Quinte
ONTARIO
QUEBEC
Ottawa
Montreal
Toronto
MOIRA RIVER STUDY

REFERENCE

PROVINCE INSET MAP TAKEN FROM ESRI CDS FROM THE ARCVIEW SOFTWARE
BASE MAP PROVIDED BY GIS GOLDER MISSISSAUGA

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Golder Associates

THE MOIRA RIVER WATERSHED

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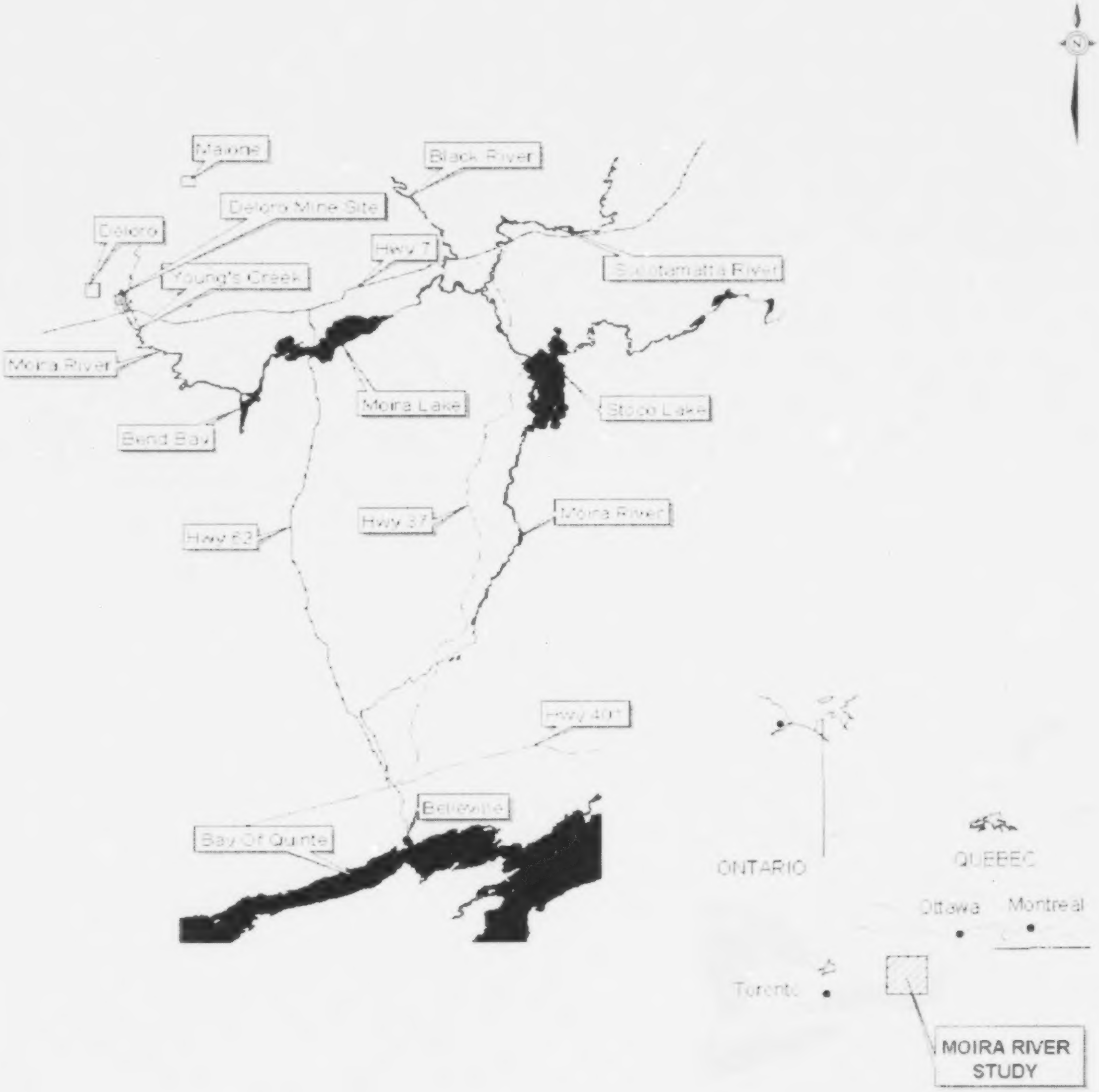
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THE MOIRA RIVER WATERSHED

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Mine Site - from arsenic to radioactivity. The proposed interim Provincial Water Quality Objective (PWQO) for arsenic of 5 µg/L (micrograms per litre) will be one of the cleanup objectives. The ministry proposes to meet this interim PWQO on average, at the Highway 7 site boundary. This is significantly more stringent than the current PWQO of 100 µg/L for arsenic.

The ministry also conducted a comprehensive Environmental Health Risk Study in the Village of Deloro. This study, released in July 1999, showed that the levels of arsenic and other metals present in the Village of Deloro are safe.

The *Moira River Study* was commissioned by the Ministry of the Environment (MOE) in 1999 to determine the extent of effects from the Deloro Mine Site on the Moira River and to predict the environmental response to the final cleanup of the site. The MOE established a Steering Committee to direct and oversee this Study. This committee included technical staff from the MOE and representation from the Ministry of Natural Resources, Quinte Conservation Association and the Hastings and Prince Edward Counties Health Unit. Phase I of the *Moira River Study*, carried out by Water Systems Analysts (W B. Kilgour), C. Portt and Associates and Dr. D.G. Dixon (University of Waterloo), was completed in February 1999. Phase I involved the review of existing studies of the Moira River watershed. Information gaps were identified and a detailed study design was developed for Phase II: a comprehensive assessment of the aquatic environmental effects on the Moira River below the Deloro Mine Site downstream to Belleville. The Steering Committee and the Moira Lake Property Owners' Association provided input to the study design.

Golder Associates Ltd. (Golder), in association with GlobalTox International Consultants Inc. (GlobalTox) was retained in April 1999 to implement Phase II of *The Moira River Study*. Phase II included a comprehensive assessment by Golder of the aquatic effects in the Moira River system attributable to the mining, mineral processing and refining activities conducted at the Deloro Mine Site. Aquatic life in the Moira River system has been exposed for more than 100 years to a variety of effluents from the Deloro Mine Site. This study presented a unique opportunity to examine the long-term aquatic effects associated with metal mining, processing and refining activities.

Phase II of *The Moira River Study* also included a preliminary quantitative risk assessment (PQRA) to determine if the observed metal concentrations could pose a potential health risk to the residents and recreational users of the watershed. GlobalTox conducted this component of the study.

The third component of Phase II of the *Moira River Study* was predictive water and sediment quality modelling conducted by Golder to assess the effects of the final cleanup of the Deloro Mine Site. The final cleanup plan for the Deloro Mine Site is currently being developed by the ministry.

The *Moira River Study* Steering Committee reviewed the draft Phase II report of this study. The draft has also been "peer reviewed" by a panel of international experts in the fields of biology, chemistry, toxicology, radioactivity, environmental modelling and risk assessment. The report was finalized to address comments from the Steering Committee, the peer reviewers and comments received from the public during the public consultation period that ended on September 26, 2000.

This introductory section addresses the context of this study, the site setting, the study objectives, the study program, discussion of applicable guidelines and reference site selection.

1.2 Study Context

One hundred years of mining, mineral processing and refining operations at the Deloro Mine Site have generated a wide variety and significant quantity of waste materials abandoned around the site. A detailed discussion of the history of the Deloro Mine Site and the extensive investigations and mitigative measures implemented are beyond the scope of this report.

A number of studies have been conducted downstream of the Deloro Mine Site to assess the presence of mine-derived metals. The findings from these studies have been considered where appropriate. These studies have included:

- Surface water quality survey that included nutrients and metals analyses (OWRC 1960);

- Biological survey (Owen and Galloway 1969); and
- Aquatic sediments (Mudroch and Capobianco 1980; Cornett and Chant 1986; Cornett *et al* 1987; Azcue and Nriagu 1993).

These studies have focussed on arsenic, metals and radionuclides in water and sediment, and to a lesser extent, in biota. These studies have shown elevated concentrations, principally arsenic, are present in the water and sediment. The ecological significance of these occurrences has not been addressed in detail since an initial study conducted in 1969 (Owen and Galloway 1969).

Beginning in 1964, an extensive water quality database has been compiled by the MOE from monthly water quality sampling conducted at as many as 23 stations within the Moira River system. This program was conducted as part of the Provincial Water Quality Monitoring Network under the direction of the MOE's Environmental Monitoring and Reporting Branch. Since 1993, this database has been augmented with the results of weekly water quality sampling conducted at 8 stations on and in the vicinity of the Deloro Mine Site. This sampling was conducted by the Ontario Clean Water Agency (OCWA), the operators of the onsite treatment plant.

A number of monitoring programs are being conducted in the watershed. While not necessarily specific to the Deloro Mine Site, these programs have also provided useful data that have been incorporated into this study where appropriate. These are:

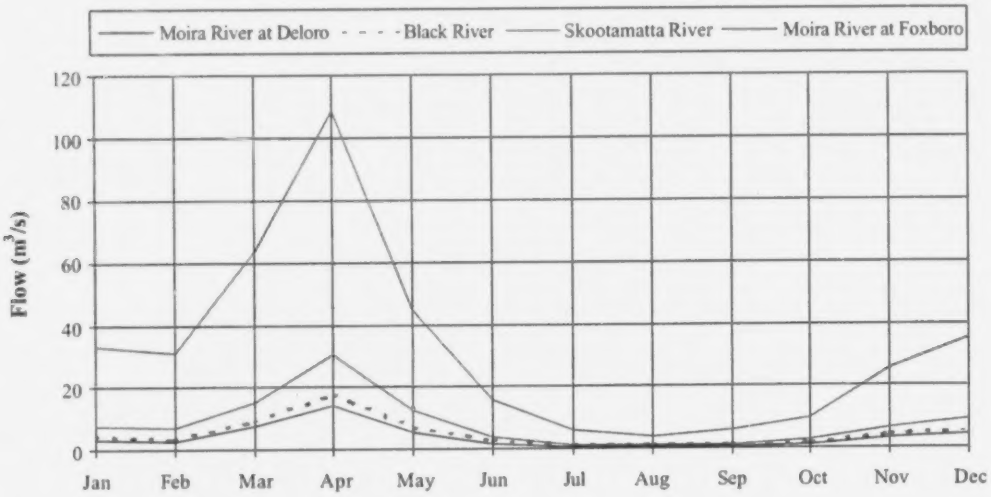
- MOE Provincial Water Quality Monitoring Network Program; and
- MOE/MNR Sport Fish Contaminant Monitoring Program.

1.3 Study Setting

The Moira River Watershed

The Moira River watershed lies north of the Bay of Quinte. It is irregular in shape and is approximately 56 miles (90 kilometres) long by a maximum of 32 miles (51.5 kilometres) wide. It occupies an area of approximately 1,056 square miles (2,735 square kilometres) and is bounded by the Trent River, Mississippi River and Salmon River watersheds (Barrens 1960). Both Moira and Stoco lakes lie on the main channel of the Moira River. The principal tributaries, the Black and Skootamatta rivers, join the Moira River from the north between these two lakes (Figure 1.1-1). The headwaters of the Moira River, as well as the entire Black and Skootamatta River watersheds, are located on the Precambrian rock of the Canadian Shield. As the Moira River flows southward through the lakes and beyond, it passes over the mostly thin glacial clay and till deposits and limestone outcrops of the Napanee Plain before emptying into the Bay of Quinte at Belleville (Ostray and Singer, 1981). Average monthly flows in the Moira River at Highway 7 vary from 14.3 m^3/sec to a low of 0.3 m^3/sec with a mean annual flow of 3.8 m^3/sec. Average monthly water flows in the Moira River and its two main tributaries, the Black and Skootamatta rivers, are shown in Figure 1.3-1.

Figure 1.3-1
Average Monthly Flows in the Moira, Black and Skootamatta Rivers (1965 to 1999)



The headwaters of the Moira River and the entire flow of the Black and Skootamatta rivers are "tea-stained" by natural decomposition of vegetation. This is typical of watercourses on the Canadian shield.

The river's form and substrate composition are affected considerably by the local geology. On the Canadian Shield, these rivers flow through occasional sluggish beaver ponds and tumble over bare rock outcrops and through bedrock chutes. Substrates range from fine organic material in slack water areas such as beaver ponds, to bare bedrock chutes with varying amounts of sand to boulder-sized particles weathered out of the outcrops. Habitats in these sections of the rivers are relatively unproductive. Fish and invertebrate populations are small and form communities of relatively low species diversity.

Beginning north of the Deloro Mine Site near Malone and continuing downstream towards Bend Bay, the Moira River encounters patchy till deposits overlying the bedrock. Here the river flows over occasional shallow rocky riffles characterized by relatively abundant and diverse fish and invertebrate communities. Substrates are rocky and sandy, with bare bedrock outcrops and limited areas of deposition of fine grained sediments consisting of silt and organic material.

Above Bend Bay, the river leaves the shield and begins to flow over glacial till deposits. Here the river is wider and flow is sluggish. Moira and Stoco lakes lie on this section of the river. These lakes are small relatively narrow and deep and have acted as traps for the accumulation of sediment. Both Moira and Stoco lakes have highly productive plankton and aquatic plant-based food webs that support diverse fish communities.

Downstream of Stoco Lake, the Moira River continues south across the Napanee Plain through small mill communities like Roslin and Latta and through Belleville. Substrates are generally rocky, owing to the thinly covered limestone of the Napanee Plain. Depositional areas are limited, usually occurring in the small headponds located above the mill dams. The Moira River is wide and shallow with rocky substrates as it discharges into the Bay of Quinte.

Land Use

Land use within the Moira River watershed is primarily mixed agriculture with recreational activities focussed around Moira and Stoco lakes and downstream on the Moira River. Historically, small-scale mining activities were conducted in the area beginning in about 1866. By 1871, seven mines were being worked in the Moira River watershed (CHRML 1987). Operations at these mines ceased early in the 1900s.

In the north end of the watershed, small communities such as Malone and Deloro are located among the farms and scattered cottages. There are few residents located along this section of the Moira River and opportunities for recreation are limited by the rocky nature of the river substrate.

Agricultural practices on the mostly thin soils and rocky outcrops of the watershed comprise primarily forage crops and mixed livestock, with extensive areas of unimproved lands.

Highway 7 traverses the area in an east west direction and is located generally in the vicinity of the southern limit of the Canadian Shield. Highway 7 crosses the Moira River immediately south of the Deloro Mine Site and just above the junction of Young's Creek with the Moira River.

Farther down the river are the larger towns of Madoc and Tweed located along the route of Highway 7 and associated with Moira and Stoco lakes, respectively. Cottages, campgrounds and parks encircle each of Moira and Stoco lakes and provide access to a variety of recreational activities for local residents and visitors; including swimming, fishing, boating and watersports in the summer and ice fishing, cross country skiing and snowmobiling in the winter. It is estimated that there are about 624 residences between the Deloro Mine Site and the outlet of Stoco Lake, of which about half are cottages. Highways 37 and 62 traverse this area connecting Highway 7 to Highway 401 that crosses the Moira River near Belleville to the south.

Downstream of Stoco Lake small communities like Roslin and Latta are located at mill sites and existing dams on the Moira River. The City of Belleville is located south of Highway 401 at the mouth of the Moira River. Industry is limited within the watershed and most of it is concentrated within and around Belleville and the major transportation route of Highway 401.

1.4 Study Objectives

The objective of the aquatic environmental effects study (AEES) of Moira River was to characterize the extent and significance of aquatic environmental effects downstream from the former Deloro Mine Site. The study design was developed to clearly determine the extent and 'ecological significance' of metal concentrations in the Moira River system by addressing the following questions:

1. Are metals entering the Moira River system?
2. Is there a measurable biological response in aquatic invertebrates and fish?
3. Are the metals in the system causing the biological response observed in invertebrates and fish?

4. Do the metal concentrations present in water and sediment of the Moira River system pose a risk to human health?
5. What amount of cleanup would be necessary at the Deloro Mine Site to meet Provincial Water Quality Objectives in the Moira River and to reduce sediment concentrations to below concentrations associated with biological effects?

The following task-specific objectives addressed the three sections of the Moira River Study: (1) AEES; (2) human health risk assessment; and, (3) predictive water quality model.

I. AEES Objectives

The objectives specific to the AEES were as follows:

- Obtain water and sediment quality data from representative stations in the Moira River system and appropriate reference locations and evaluate for temporal and spatial trends including historical water quality trends;
- Obtain benthic invertebrate community data from the Moira River system and reference locations and evaluate for relationships with metal concentrations; and
- Obtain data for two sentinel fish species and evaluate the population-level and whole organism responses for possible relationships with metal concentrations.

II. Human Health Risk Assessment

This consisted of a Preliminary Quantitative Risk Assessment (PQRA), the objective of which was to determine if the metals released to the Moira River system pose a potential health risk to people in the Moira River watershed.

III. Predictive Water Quality Model

The objective of the modelling component was to develop and implement a decision support model to predict sediment and water quality in Moira and Stoco lakes for selected metals. The model predicted the water and sediment quality resulting from various levels of future cleanup activities to be conducted at the Deloro Mine Site, and the time period that would be required to achieve sediment and water quality guidelines or objectives at downstream locations.

1.5 Study Program

A study program had previously been developed by WSA (1999) as Phase I of the MOE's *Moira River Study*. Some minor modifications were made to this study design on the basis of a detailed review conducted by Golder and experience gained during an initial site reconnaissance. These refinements were as follows:

1. Sediment toxicity testing was conducted at the same stations where benthic invertebrates are collected (including reference locations). The toxicity data would then coincide more closely with the benthic invertebrate community data, completing the Sediment Quality Triad. A subset of stations representing a broad range of metal concentrations were selected for toxicity testing and a broad range of metal concentrations was tested.
2. Sediments were tested within six weeks of collection.
3. Seasonal cycles were examined for water quality.
4. Metals in longnose dace were measured instead of benthic invertebrates because of insufficient invertebrate abundance.
5. For benthic invertebrates, a series of locations along a reference river were examined to assess changes with increasing distance downstream.
6. For fish studies, longnose dace were sampled in the fall rather than the spring.

In summary, the following activities were completed for the Phase II component of the *Moira River Study*:

- Selection of reference and exposed sites;
- Spring survey for longnose dace;
- Spring collection of sediments for chemistry (66 grab sample sites), laboratory toxicity testing (at 27 of the 66 grab sample sites) and benthic invertebrate sampling (at 36 of the 66 grab sample sites);

- Summer survey of lake water temperatures and dissolved oxygen profiles in Round, Consecon, Moira and Stoco lakes;
- Mail/hand out water use questionnaire;
- August sediment core sampling (11 sample sites);
- Fall sampling program for sentinel fish species (119 of 257 longnose dace and 123 of 207 white sucker processed for effects parameters);
- Preliminary quantitative risk assessment;
- Predictive water quality modelling;
- Data compilation, interpretation and analysis; and
- Reporting.

The study area consisted of almost the entire Moira River system from upstream of the Deloro Mine Site to Belleville at the Bay of Quinte. Reference sites located within the watershed included the Moira River upstream of Malone, and the Black and Skootamatta rivers. Reference sites located outside of the watershed include the Salmon River, and Round and Consecon lakes.

The environmental components of the study included water quality, sediment quality, benthic invertebrate communities and fish communities. Each component is detailed in subsequent chapters of this report.

This project is limited to the spring, summer and fall of 1999 and the winter of 1999/2000, with the majority of the field work occurring in the spring and fall of 1999.

1.6 Discussion of Applicable Guidelines

Water quality data used in the AEES have been compared to the Provincial Water Quality Objectives (PWQO) (MOE 1999a). The PWQOs were developed to be protective of aquatic life, but are not direct measurements of aquatic ecosystem health. The PWQOs include objectives for uranium and radium-226, two of the radionuclides measured in this study. Where objective values are not being met, all practical measures are to be taken to improve water quality (MOE 1999a). As is discussed in Section 2.1, water quality data were screened for metals that exceeded PWQOs to identify the metals of concern for the aquatic environmental study. If a PWQO was not available for a particular metal or radionuclide, concentrations were compared to reference concentrations at reference sites.

The ministry has stated that the interim PWQO for arsenic is to be adopted as one of the objectives of the final cleanup plan to be developed for the Deloro Mine Site. The interim PWQO for arsenic is 5 µg/L, which is much more stringent than the current PWQO of 100 µg/L. The interim PWQO for arsenic was considered only in the section of this report addressing the predicted response to the aquatic system to future cleanup actions (Section 4). Elsewhere, current PWQOs have been used to examine the water quality data.

Sediment quality data used in the AEES were compared to the Provincial Sediment Quality Guidelines (PSQGs) (MOE 1993). The PSQGs were developed for the protection of aquatic life and contain a set of guideline concentrations in sediment, expressed as lowest and severe effects levels (LELs and SELs). These concentrations, or effects levels, are not a direct measure of the health of an aquatic system. Exceedances of LELs or SELs typically indicate the need to conduct biological testing of aquatic organisms (MOE 1993). Consistent with this requirement, the *Moira River Study* included the assessment of the aquatic environment including benthic invertebrates and fish species. Sediment guideline values have not been developed for some parameters (e.g., cobalt), in which case, the MOE have detailed the methodology by which site specific screening level concentrations (SLCs) are to be developed. SLCs were developed for two of the metals under consideration, as discussed in Section 2.2

Water quality data used in the PQRA were compared to Ontario Drinking Water Objectives (ODWO) (MOE 1999a) to identify metals of concern for human health. If an ODWO was not available for a particular metal, criteria from Table A (potable groundwater) of the MOE Cleanup Guideline were used (MOE 1999b). Both the ODWOs and Table A criteria represent safe concentrations for human health.

1.7 Reference Site Selection

The *Moira River Study* required the selection of reference rivers and lakes to compare with the Moira River and Moira and Stoco lakes. Information on lakes and rivers in the Moira River watershed and adjacent watersheds was obtained from the Kingston Ministry of the Environment

(MOE), the Quinte, Cataraqui Region, Crowe Valley, Napanee Region, Lower Trent Region, and Mississippi Valley Conservation Authorities, as well as the Peterborough, Bancroft and Kingston offices of the Ministry of Natural Resources (MNR). Water Survey of Canada data records were reviewed for substrate, water quality and quantity information.

All reference river and lake sites were selected based on a review of background information and two site reconnaissance surveys undertaken on April 20 - 23, and 29 - 30, 1999. Information was obtained regarding water quality and quantity; however, limited data were available on the type and quality of aquatic habitat and on the fishery of the rivers that were being evaluated as potential reference sites. Information on lakes was more readily available and numerous lakes were considered as potential reference locations in discussions with MOE, MNR and Conservation Authority staff.

Based on a review of existing information, primary and secondary screening factors/criteria were established for reference site selection. Chemical and physical data of candidate lakes and rivers were compared to those of Moira Lake, Stoco Lake and Moira River. Primary screening factors established for lake reference site selection included basin and watershed geology, retention time, thermal stratification, oxygen depletion/profile, trophic status, maximum and mean depth, hardness, alkalinity and pH, shoreline development, fish community composition and potential metal sources. Secondary factors included the presence of alga blooms and aquatic vegetation, lake size and volume, drainage basin area, study area proximity and access.

River reference site selection incorporated the following primary screening factors: geology, gradient, habitat complexity/dominance, flow, velocity, hardness, alkalinity, pH, potential metal sources, average wetted stream width and depth. The secondary screening factors included drainage area, water colour, substrate, study area proximity and access and elevation.

Based on an evaluation of primary and secondary screening factors, Round Lake and Consecon Lake were considered most similar to Moira and Stoco lakes in terms of physical and chemical characteristics and were selected as the reference lakes. Benthic invertebrate, sediment toxicity and sediment chemistry samples were collected at the inlet, outlet and deep basin in each of the four lakes plus one additional mid-basin sample from Consecon Lake, to ensure that an oxygen-depleted condition was represented.

The selection of river reference sites took into consideration that Moira River is physically different upstream and downstream of Bend Bay. A total of four (4) reference sites were selected to compare with the upstream section of Moira River (between the Deloro Mine Site and Bend Bay). One reference station was selected on each of the Black and Skootamatta rivers and two were selected on the Moira River upstream of the Deloro Mine Site near Malone. A total of three (3) reference sites were selected on the Salmon River to correspond with the downstream reach of Moira River (Figure 1.1-1). Benthic invertebrates, sediment toxicity and sediment chemistry were sampled at 7 reference river sites and at 8 exposed river sites.

1.8 Report Organization

The report is separated into chapters that cover the different components of the study. Chapter 2 details the aquatic environmental effects of the mine on the Moira River system, and has subsections discussing water quality (Section 2.1), sediment quality (Section 2.2), benthic invertebrate communities (Section 2.3), metals concentrations in fish tissue (Section 2.4), and fish sentinel species (Section 2.5). Chapter 3 discusses the preliminary quantitative risk assessment for human health. Chapter 4 details the predictive modelling of metal concentrations in the river system. Chapter 5 provides conclusions and recommendations. Most chapters have relevant appendices containing data and other backup information.

1.9 Acknowledgements

The assistance of the Ministry of the Environment and the Ministry of Labour in completing this study is gratefully acknowledged. This includes staff of the:

- Environmental Monitoring and Reporting Branch who most ably completed the collection of sport fish, benthic invertebrates and sediments, and assisted with sentinel fish;
- Laboratory Services Branch who conducted the analyses of metals;
- Ministry of Labour Radiation Protection Monitoring service staff who conducted the analyses of radionuclides; and
- Quinte Conservation Association who contributed in collecting the water quality monitoring program samples.

This study could not have been completed without the willing cooperation of these staff.

This report has benefited from the thorough review conducted by internationally recognized experts selected by the MOE as the peer reviewers for this *Study*. These experts were:

- Dr. Charles Abernathy, U.S. Environmental Protection Agency
- Dr. Gerald Ankley, U.S. Environmental Protection Agency
- Dr. Henry Caplan, University of Saskatchewan
- Dr. William Cullen, University of British Columbia
- Dr. Peter Hodson, Queen's University
- Dr. Alex McCorquodale, University of New Orleans
- Dr. Kelly Munkittrick, University of New Brunswick
- Dr. Chris X-Le, University of Alberta

1.10 References

Azcue, J.M. and J.O. Nriagu. 1993. Arsenic forms in mine polluted sediments of Moira Lake, Ontario. Environment International, 19:405-415.

Barrens, R. 1960. Report on Water Pollution Survey of the Moira River System. Ontario Water Resources Commission. 25 p.

Commonwealth Historic Resource Management Limited, 1987. A historical analysis of the Deloro Site. Draft report prepared for J.L. Richards & Associates, November 1987.

Cornett, J., L. Chant and B. Risto. 1992. Arsenic transport between water and sediments. Hydrobiologia, 235/236:533-544.

Mudroch, A. and J.A. Capobianco. 1980. Impact of past mining activities on aquatic sediments in the Moira River basin, Ontario. International Association for Great Lakes Research, 6:121-128.

Ontario Department of Planning and Development (ODPD). 1955. Moira Valley Conservation Report, Summary. Toronto.

Ontario Ministry of the Environment (MOE) 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Queens Printer for Ontario

Ontario Ministry of the Environment and Energy (MOE) 1999a. Water management policies: guidelines, provincial water quality objectives. Queens Printer for Ontario. Toronto, ON.

Ontario Ministry of the Environment and Energy (MOE) 1999b. Guidelines for use at contaminated sites in Ontario. Queens Printer for Ontario. Toronto, ON.

Ostray, R.C. and S.N. Singer. 1981. The Hydrogeology of the IFYGL Moira River, Wilton Creek and Thousand Islands Study Areas. Ontario Ministry of the Environment Water Resources Report 5e. 40 p.

Owen, G.E. and D.L. Galloway. 1969. Biological survey of the Moira River. Ontario Ministry of the Environment.

WSA. 1999. Moira River impact study: Detailed study design to determine the impact of the former Deloro Mine Site on the Moira River system. Final Report to Ontario Ministry of Environment.

2. AQUATIC ENVIRONMENTAL EFFECTS OF THE FORMER DELORO MINE SITE ON THE MOIRA RIVER SYSTEM

2.1 Water Quality

2.1.1 Water Quality Methods

Sources of Water Quality Data Used in This Study

Water quality data and station locations were obtained from the Ministry of the Environment (MOE) Provincial Water Quality Monitoring Network Program (PWQMNP) (MOE 1964 to 1999). A large proportion of the data was obtained electronically and placed in a Microsoft Access database. During 1996, the MOE upgraded their database. Some data gaps were identified for the period 1996 to present. Hard copy of some additional data were made available and manually entered into the Access database. The PWQMNP includes the routine analysis of several metals, nutrients and other parameters such as dissolved oxygen and turbidity. Analytical methods used for the PWQMNP are listed in Appendix I.

Data gaps exist within the PWQMNP. Not all sampling stations were sampled each year. These data gaps are identified by the notation "ND" in Table 2.1-1. There were some years where no data were available for a particular metal. The years where no measurements were recorded at any sampling station for each parameter are identified below (note: data for some of the following parameters and dates were available for stations sampled at and near the Deloro Mine Site by the Ontario Clean Water Agency):

- Arsenic 1998;
- Cobalt 1980 to 1984 and 1987;
- Hardness 1977 to 1987;
- Lead 1973 to 1975;
- Dissolved Oxygen 1994 to 1997; and
- Nickel 1980-1981 and 1983-1984 and 1987.

Silver and uranium were analyzed only once during the period of record. The remaining analytes in Table 2.1-1 (i.e., copper, pH, stream flow, suspended solids and turbidity) represent a continuous data set for most sampling stations for the sampling periods identified.

Table 2.1-1
Historical Provincial Water Quality Network Data Collection: Selected Relevant Parameters

Parameter	Sampling Period		Number of Samples Collected per Network Station (W) for Chemicals of Concern																							
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	23	24	DM1	DM 7	DM8
Arsenic	1964	1999	382	495	4	446	32	502	8	8	462	493	498	419	439	47	472	11	492	ND	ND	453	36	481	78	74	60	60
Cobalt	1979	1999	65	96	ND	24	ND	78	15	8	26	27	26	18	26	ND	25	ND	27	6	5	26	ND	27	33	34	20	20
Copper	1972	1999	66	98	ND	53	ND	146	15	8	54	138	55	42	153	ND	54	ND	57	6	5	165	ND	191	33	34	20	20
Dissolved oxygen	1964	1998	157	220	ND	173	21	237	ND	ND	176	213	214	155	190	42	194	ND	204	1	2	251	36	274	7	ND	ND	ND
Hardness	1965	1999	26	77	ND	68	10	76	7	ND	65	85	85	60	99	16	75	ND	80	5	5	155	24	126	25	ND	ND	ND
Lead	1972	1999	65	97	ND	53	ND	146	15	6	54	138	56	42	154	ND	54	ND	57	6	5	148	ND	191	33	44	44	44
Nickel	1972	1999	66	98	ND	52	ND	81	15	8	54	58	56	42	89	ND	54	ND	57	6	5	127	ND	102	33	74	60	60
pH	1964	1999	66	128	1	70	13	186	6	ND	62	153	83	59	166	16	73	8	82	5	5	194	32	219	27	ND	ND	ND
Silver	1987	1987	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	ND
Solids; suspended	1997	1999	ND	10	ND	5	ND	ND	10	4	12	11	11	7	11	ND	11	ND	11	ND	ND	11	ND	10	15	ND	ND	ND
Stream flow	1964	1989	ND	399	ND	ND	ND	ND	ND	ND	372	423	60	ND	ND	ND	ND	ND	ND	ND	ND	346	ND	8	ND	ND	ND	ND
Turbidity	1964	1999	133	247	ND	176	19	289	10	4	149	244	191	134	237	44	175	ND	182	5	5	312	39	309	33	ND	ND	ND
Uranium	1991	1991	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND: No Data.
DM: OCWA Station; 1993-1999.

Beginning in 1993, an intensive surface water monitoring program was initiated to collect daily and weekly water quality samples for aluminum, arsenic, nickel, lead, mercury, cobalt, copper, molybdenum and zinc in close proximity to the Deloro Mine Site. Results from station numbers DM1, DM7 and DM8 from the intensive study were added to the database for this study (see Table 2.1-1). Water quality data from the remaining stations DM2, DM3, DM4, DM5 and DM6 are not representative of the Moira River downstream of the Deloro Mine Site and were not considered in this study. The intensive program is conducted by the Ontario Clean Water Agency (OCWA) who operate the treatment plant at the Deloro Mine Site.

Some parameters measured in the PWQMNP were frequently less than detection limits (Table 2.1-2). The total number of samples collected for selected relevant parameters and the number of samples that yielded results below detection are identified in Table 2.1-2. There were no quality control samples included within the PWQMNP data set. It should be noted that detection limits declined significantly over the period of record (see later discussion).

Table 2.1-2
Total Number of Samples Collected and the Percent of Results Found Below Detection Limits for Selected Relevant Parameters

Parameter	Total Samples Collected	% Results Below Detection
Arsenic	6452	32%
Cobalt	632	15%
Copper	1413	13%
Dissolved oxygen	2767	0%
Hardness	1169	0%
Lead	1454	71%
Nickel	1197	37%
pH	1654	Not Applicable
Silver	1	0%
Solids; suspended	139	0%
Stream flow	1608	0%
Turbidity	2937	0%
Uranium	1	0%

See Figure 2.1-2 for changing detection limits over time.

The database for this study was augmented in 1999 and 2000 by the analysis of selected water quality samples for radioactivity. This was the only water quality analysis conducted specifically for this study. The samples were collected by MOE from stations at Stoco Lake, Moira Lake Narrows at Highway 62, Moira Lake Outlet, Moira River at Highway 7 and Malone. Samples were submitted to the Ministry of Labour, Radiation Protection Monitoring Service, evaporated and analyzed for the following parameters:

- Radium-226;
- Radium-228;
- Thorium-228;
- Uranium-238;
- Gross alpha activity; and
- Gross beta activity.

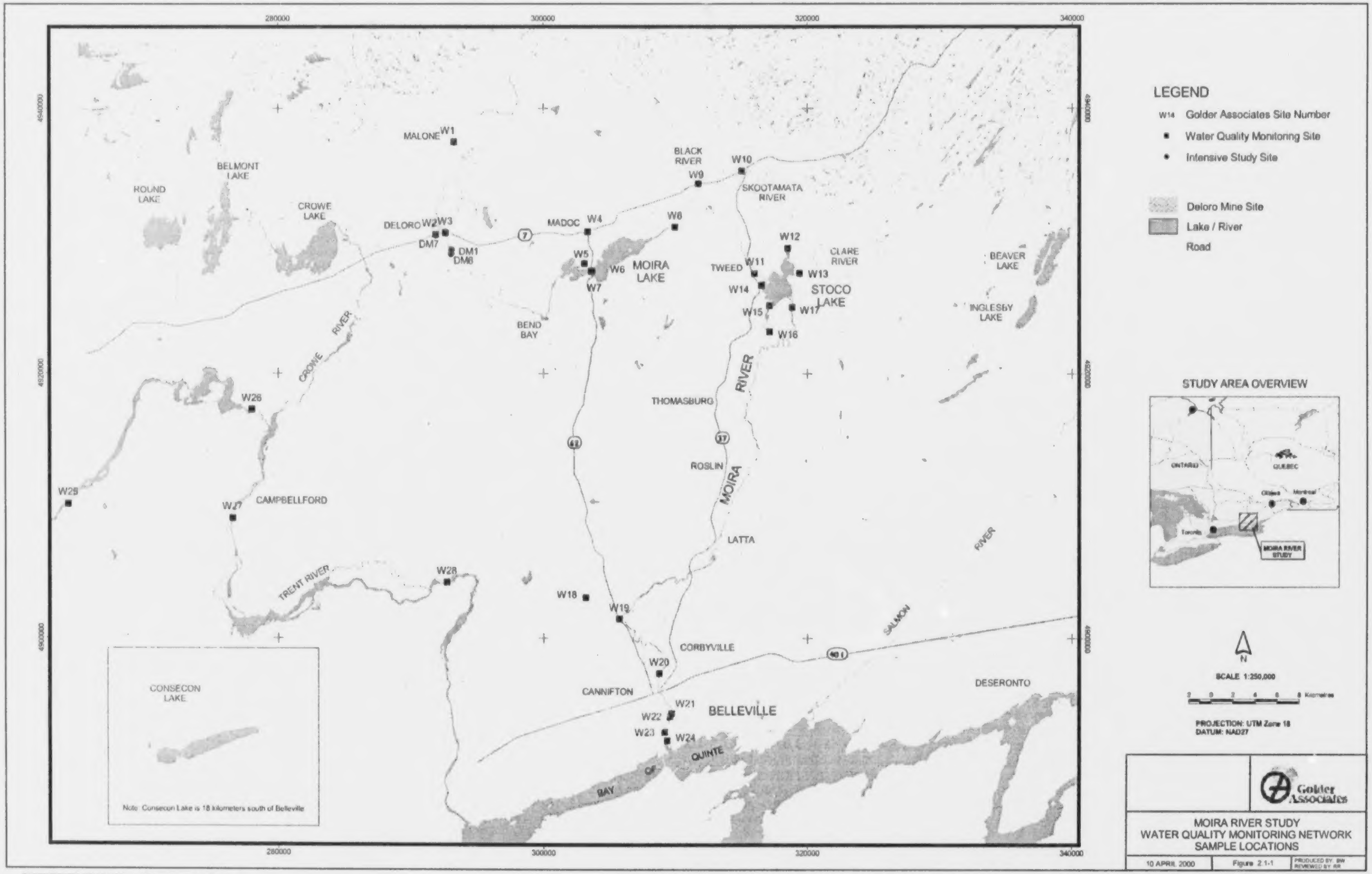
A description of the analysis for radionuclides is included in Appendix I.

Water quality station numbers, names and descriptions are provided in Table 2.1-3 and shown on Figure 2.1-1. The water quality sites have been numerically labelled in order of upstream/Malone to downstream/Belleville (i.e., Station Numbers 1-24). Station 21 was removed from the data set because no data have been collected to date.

Results found to be below detection were incorporated in the calculation of annual averages by using the detection limit as the value. Incorporating the value of the detection limits could bias the annual averages for arsenic, lead and nickel since 32% to 71% of results (Table 2.1-2) are at the limit of detection. Thus, the actual averages may be lower than the averages calculated using the detection limit because the actual concentrations may have been considerably less than the detection limit. In addition, detection limits have been decreasing intermittently since the PWQMNP was established for the Moira River system in 1964 (Figure 2.1-2). Therefore, decreasing annual average metal concentrations may correlate with increasing precision or decreasing detection limits of analytical instruments (Bowen 1994). Dealing with detection limits was further complicated by the fact that detection limits within a year fluctuate between stations and by month depending on the set-up of the analytical instrument when the samples were analyzed.

Table 2.1-3
Identification and Description of Water Quality Stations

Water Quality Station		
Number	**General Name**	**Description**
W1	Malone	Bridge at Malone, upstream of Deloro, Madoc/Marmora Twp
W2	D/S Deloro	Hwy 7, downstream of Deloro, Marmora Twp
W3	Lily Cr	At Highway 7
W4	Deer Cr	Seymour St., Madoc
W5	Madoc Cr	At Moira Lake
W6	Hwy 62 Bridge	Hwy 62 bridge
W7	Moira Lk Narrows	Hwy 62, Huntingdon Twp. Moira Lk. Narrows
W8	Moira Lk Outlet	Moira Lake Outlet, Rapids Rd., Hungerford/Tweed Twp.
W9	Black R	Highway 7 – 2 miles east of Actinolite, Hungerford Twp.
W10	Skootamatta R	Highway 7 near Actinolite, Hungerford Twp.
W11	Stoco Lk Inlet	Jameson Street Tweed, Louisa St. Bridge
W12	Sulphide Cr	Upstream from Stoco Lake Hungerford Twp, Sulphide Rd
W13	Clare R	1st bridge upstream of Stoco Lake Tweed
W14	Beach at Tweed	Municipal beach at Tweed
W15	Stoco Lk Outlet	Stoco Lake w. channel outlet
W16	Chapmans Bridge	Chapmans Bridge
W17	Stoco Bridge	Stoco Bridge Hungerford Twp e. channel outlet
W18	Palliser Cr Quinte	Flying Club road, Quinte west(Rose Road)
W19	Palliser Cr Foxborough	Ashley Street bridge, Foxborough, 1st bridge u/s Moira R.
W20	Cannifton	Bridge in Cannifton, Maitland Rd
W21	Belleville College St	College St. Belleville
W22	Belleville CNR Bridge	CNR bridge (sewer)
W23	Belleville Hwy-2	Footbridge north of Highway 2 Belleville
W24	Belleville Victoria St	Victoria St. Belleville
W25	Hastings	Bridge Street Hastings
W26	Healey Dam	Healey Falls dam, downstream of falls
W27	Campbellford	Dam, town of Campbellford
W28	Glen Ross Bridge	Glen Ross bridge
W99	Jackson Cr	Second road north of Highway 28
DM1	Young's Creek	OCWA Intensive Study: Young's Creek at Moira River
DM7	Moira Hwy-7	OCWA Intensive Study: Upstream for Moira River at Highway #7
DM8	Moira D/S Young's Creek	OCWA Intensive Study: Moira River, Downstream of Young's Creek

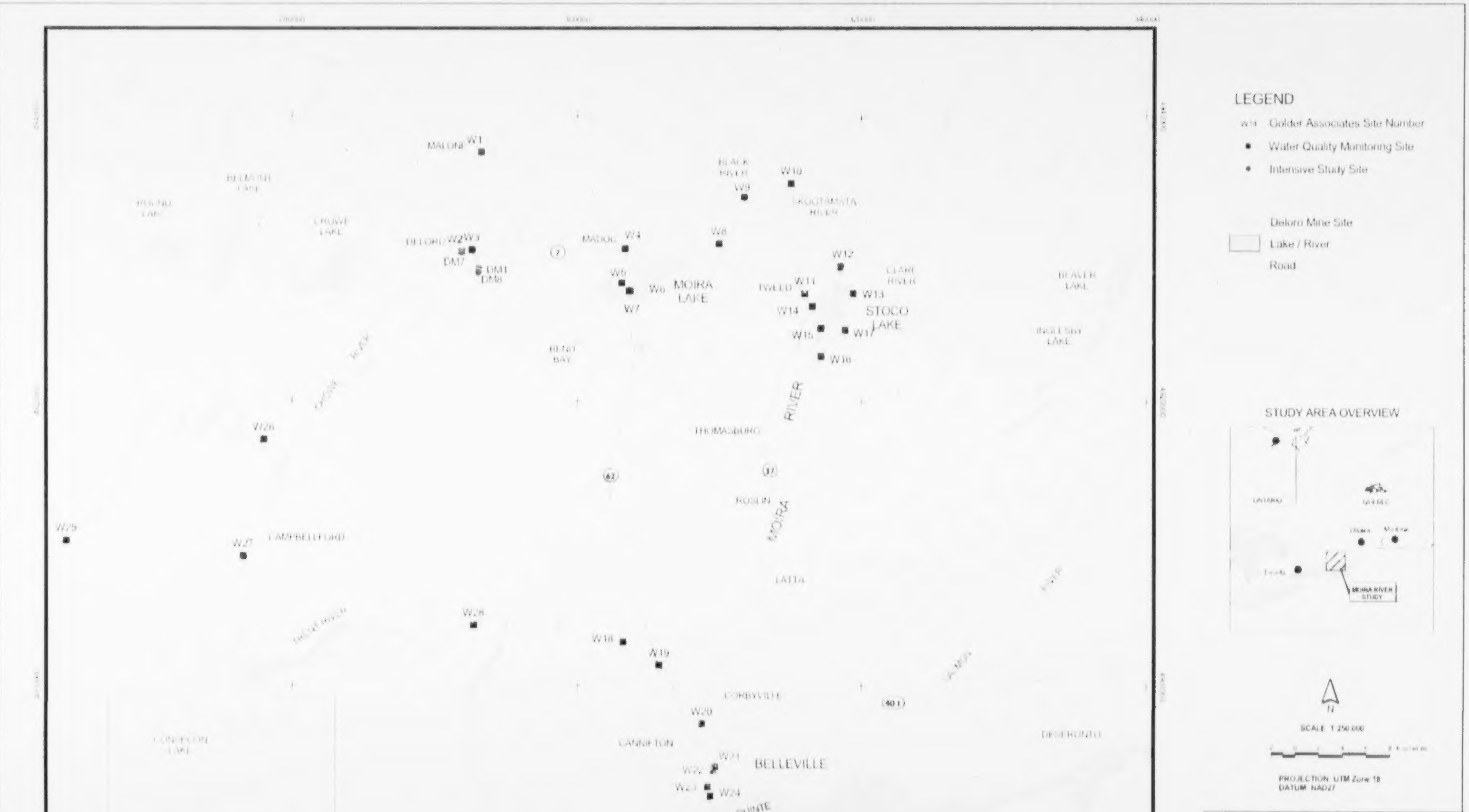

280000
300000
320000
340000
4940000
4920000
4900000
LEGEND
W14 Golder Associates Site Number
Water Quality Monitoring Site
Intensive Study Site
Deloro Mine Site
Lake / River
Road
STUDY AREA OVERVIEW
ONTARIO
QUEBEC
Ottawa
Montreal
Toronto
MOIRA RIVER STUDY
N
SCALE 1:250,000
2 0 2 4 6 8 Kilometres
PROJECTION: UTM Zone 18
DATUM: NAD27
ROUND LAKE
BELMONT LAKE
CROWE LAKE
MALONE
W1
DELORO
W2
W3
DM7
DM1
DM8
MADOC
W4
W5
W6
W7
MOIRA LAKE
W8
BLACK RIVER
W9
W10
SKOOTAMATA RIVER
W12
CLARE RIVER
TWEED
W11
W13
W14
STOCO LAKE
W15
W17
W16
BEAVER LAKE
INGLESBY LAKE
BEND BAY
CROWE RIVER
W26
THOMASBURG
RIVER
ROSLIN
MOIRA
W25
W27
CAMPBELLFORD
LATTA
TRENT RIVER
W28
W18
W19
SALMON
RIVER
CORBYVILLE
W20
CANNIFTON
W21
W22
W23
W24
BELLEVILLE
DESERONTO
BAY
OF
QUINTE
CONSECON LAKE
Note: Consecon Lake is 18 kilometers south of Belleville
7
62
37
401

Golder Associates

MOIRA RIVER STUDY
WATER QUALITY MONITORING NETWORK
SAMPLE LOCATIONS

10 APRIL 2000 | Figure 2.1-1 | PRODUCED BY: BW REVIEWED BY: RR

R:\1999\1300\991-1358\8100\Mapping\gis\aprid-moira-april10.apr


LEGEND
W14 Golder Associates Site Number
■ Water Quality Monitoring Site
● Intensive Study Site
Deloro Mine Site
Lake / River
Road
STUDY AREA OVERVIEW
ONTARIO
QUEBEC
MOIRA RIVER STUDY
N
SCALE 1:250,000
PROJECTION UTM Zone 18
DATUM NAD27
MALONE
W1
BELMONT LAKE
CROWE LAKE
DELORO
W2
W3
DM7
DM1
DM8
MADOC
W4
W5
W6
W7
MOIRA LAKE
BLACK RIVER
W8
W9
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SKOOTAMATTA RIVER
TWEED
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W17
CLARE RIVER
STOCO LAKE
BEAVER LAKE
INGLESBY LAKE
BEND BAY
RIVER
THOMASBURG
ROSLIN
MOIRA
LATTA
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CAMPBELLFORD
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CORBYVILLE
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CANNIFTON
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BELLEVILLE
QUINTE
OF
BAY
DESERONTO
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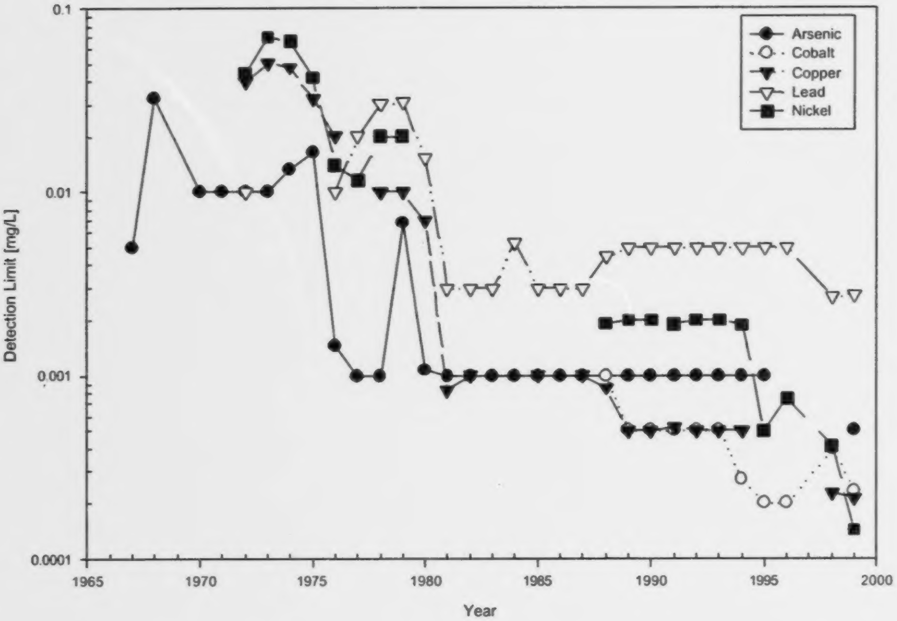
401

Golder Associates

MOIRA RIVER STUDY
WATER QUALITY MONITORING NETWORK
SAMPLE LOCATIONS

Figure 2.1-2
Annual Average Water Quality Detection Limits for Selected Chemicals



Identification of Metals of Concern

Water quality data were screened to identify the metals of concern for this study. Metals of concern were identified by comparing concentrations to Provincial Water Quality Objectives (PWQOs) (MOE 1999). In some cases, concentrations in the Moira River system downstream of the Deloro Mine Site exceeded PWQOs, but did not exceed reference concentrations. These constituents were elevated throughout the study region (including reference sites) and were assumed to represent metals with high natural background concentrations. The high natural background constituents were aluminum, cadmium, chromium, iron, and zinc.

The metals of concern for this study, and their respective PWQOs in µg/L and mg/L are:

- Arsenic: 100 µg/L (0.1 mg/L);
- Cobalt: 0.9 µg/L (0.0009 mg/L);
- Copper: 5 µg/L (0.005 mg/L);

- Lead: 5 µg/L (0.005 mg/L);
- Nickel: 25 µg/L (0.025 mg/L); and
- Silver: 0.1 µg/L (0.0001 mg/L).

These metals exceeded PWQOs at one or more stations downstream of the Deloro Mine Site, and were found at concentrations higher than at the reference sites at most or all of the stations downstream of the Deloro Mine Site. Silver was included despite the paucity of data because it is one of the more toxic metals to aquatic organisms and because it exceeded the PWQO at some stations.

Radionuclides were screened out as metals of concern in water. All uranium concentrations were less than the detection limit of 0.1 µg/L (Appendix I). Concentrations of radium-226 and thorium-228 were less than detection limits at all sample sites (Appendix I). Gross alpha activity was less than the detection limit of 0.04 to 0.05 Bq/L at all sampling stations. Gross beta activity ranged from <0.04 to 0.10 Bq/L (Appendix I). These results confirm the lack of any significant transport of radionuclides in water from the Deloro Mine Site. No significant transport in water was expected because earlier studies of the extent of radioactive materials at the Deloro Mine Site found that the materials in the slag in the Industrial Area were immobile (SCIMUS 1999). Furthermore, SCIMUS found that radioactive contamination caused by tailings transported by erosion into the upper portion of Young's Creek became indistinguishable from background upstream of Highway 7.

The metals of concern are referred to as "metals" in the rest of this report. This includes arsenic, which is commonly referred to as a metal, although it is, in fact, a metalloid.

Temperature and Oxygen Profiles

Temperature and oxygen profiles were measured in each of the four study lakes (Moira, Stoco, Consecon and Round lakes) in late August, 1999. A WTW Microprocessor Pocket Oxygen Meter (Oxi 330/set) was used to measure dissolved oxygen. Profiles were taken at locations where previous data (MNR records) indicated maximum depths.

2.1.2 Results and Discussion

Metal Concentrations with Distance Downstream of the Deloro Mine Site

The concentration of the metals of concern declined with distance downstream of the Deloro Mine Site[1] (Figures 2.1-3 to 2.1-7). The data used to prepare these figures are found in Appendix I. The relative decline with distance downstream varied with each metal. For example, recent (1995-1999) mean annual concentrations declined with distance downstream as follows:

- Arsenic: 0.01 - 0.07 mg/L in the Highway 7 bridge-to-Moira Lake (immediately downstream) section to 0.002 to 0.005 mg/L in the Stoco Lake-to-Belleville (further downstream) section.
- Cobalt: 0.001-0.09 mg/L immediately downstream to 0.0002-0.001 mg/L in the further downstream section.
- Copper: 0.001-0.02 mg/L immediately downstream to 0.0003-0.002 mg/L in the further downstream section.
- Lead: 0.001-0.01 mg/L immediately downstream to 0.0008-0.005 mg/L in the further downstream section.
- Nickel: 0.003-0.02 mg/L immediately downstream to 0.0007-0.005 mg/L in the further downstream section.

The frequency of exceedances of the PWQOs also decreased with distance downstream. Recent mean annual arsenic and nickel concentrations did not exceed the PWQO at any of the stations downstream of station W2 (on the Moira River just downstream of the Deloro Mine Site, i.e., W6, W11, W15, W17 and W23) (Figures 2.1-3 and 2.1-7; Appendix I). Recent mean annual cobalt, copper and lead concentrations did not exceed the PWQO downstream of Moira Lake (Figures 2.1-4, 2.1-5 and 2.1-6; Appendix I).

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[1] The Malone station (W1) is located upstream from Deloro Mine Site. Between Deloro and Moira Lake are (in descending elevation): Highway 7 Bridge (DM7/W2), Young's Creek (DM1) and Downstream Young's Creek (DM8). Station W6 is located in Moira Lake at the Highway 62 Bridge that crosses the lake. Downstream of Moira Lake are (in descending elevation): Stoco Lake inlet (W11), Stoco Lake outlet (W15), Stoco Lake Bridge (W17) and Belleville Highway 2 (W23).

Figure 2.1-3
Annual Mean Moira River Arsenic Levels (from Upstream to Downstream) (mg/L)

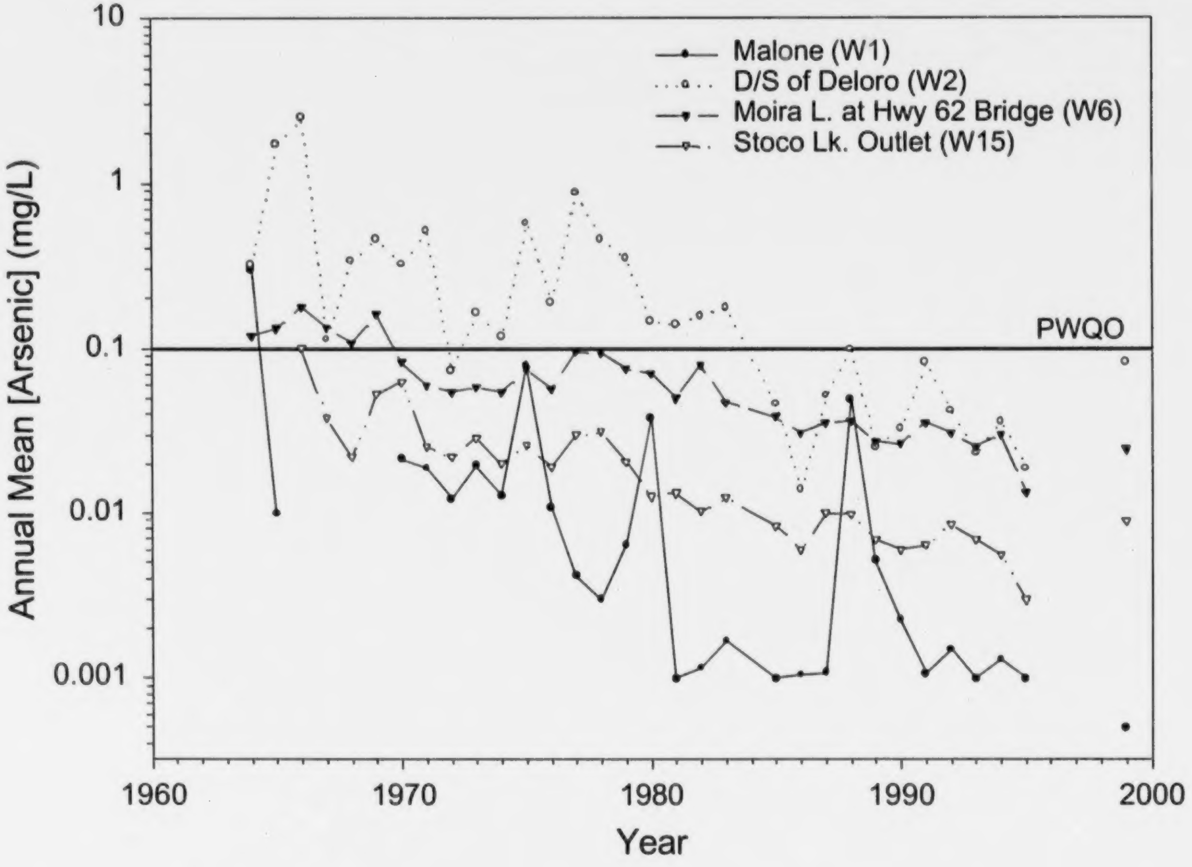


Figure 2.1-4
Annual Mean Moira River Cobalt Levels (from Upstream to Downstream) (mg/L)

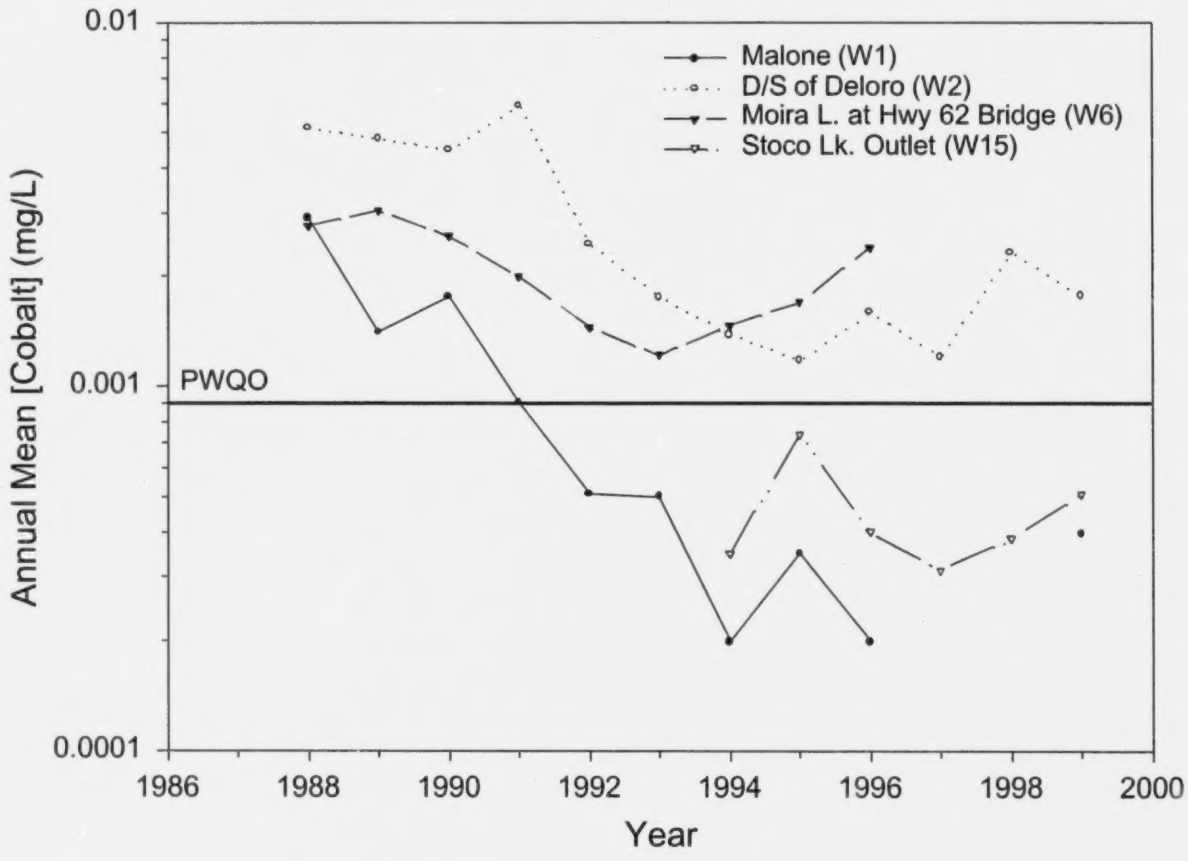


Figure 2.1-5
Annual Mean Moira River Copper Levels (from Upstream to Downstream) (mg/L)

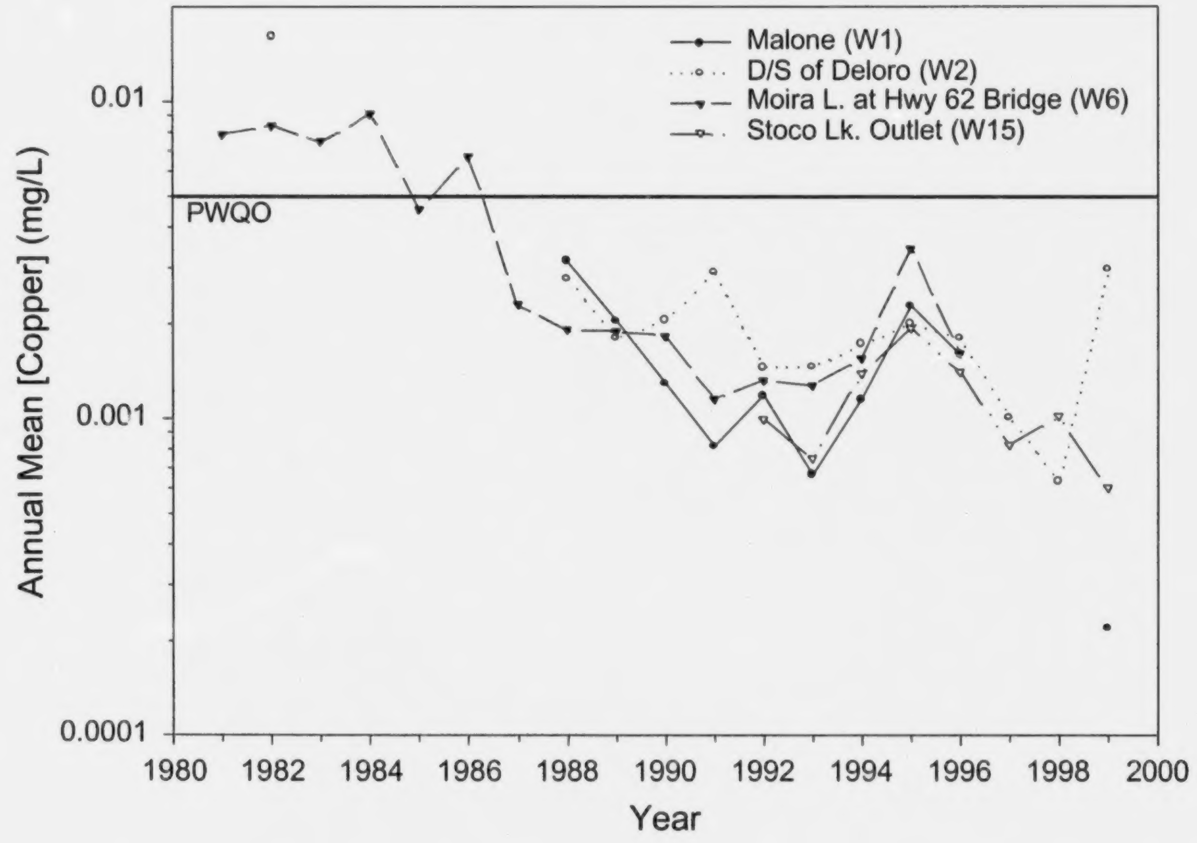


Figure 2.1-6
Annual Mean Moira River Lead Levels (from Upstream to Downstream) (mg/L)

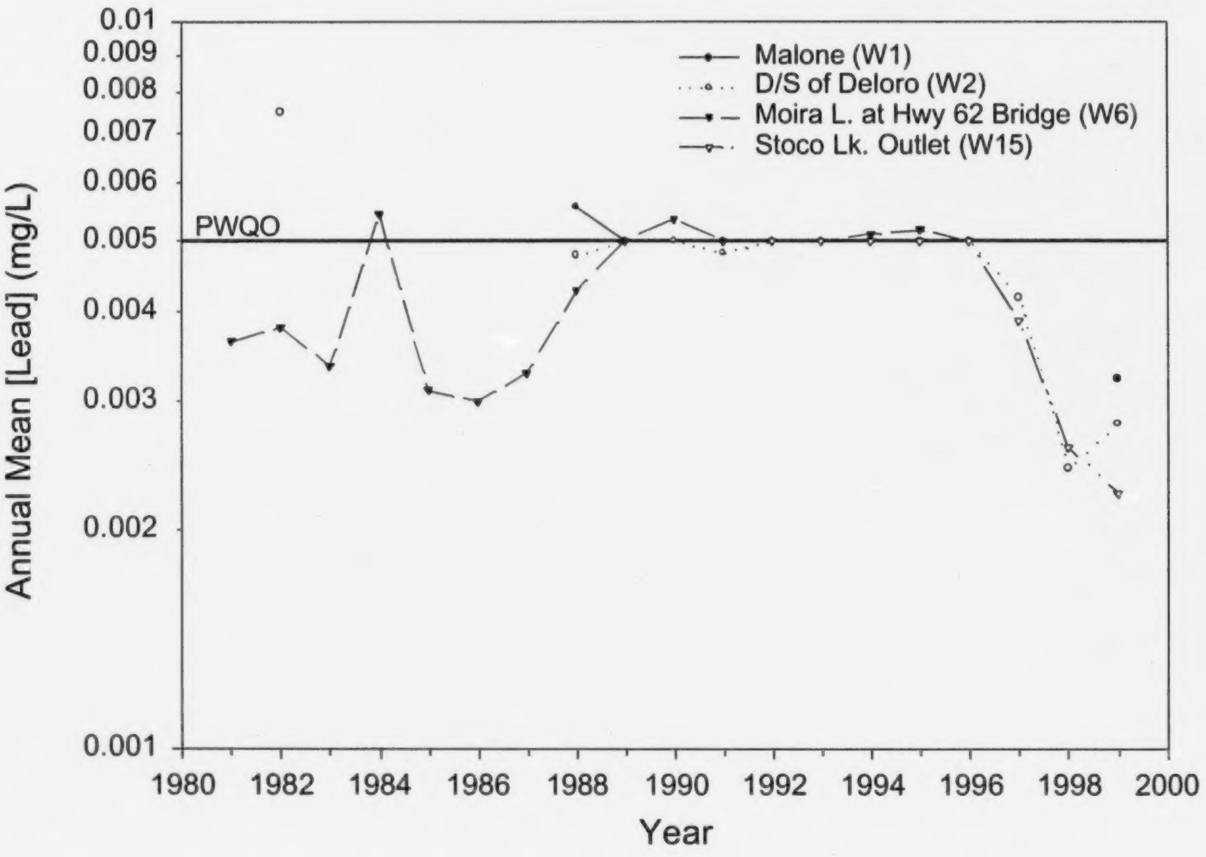
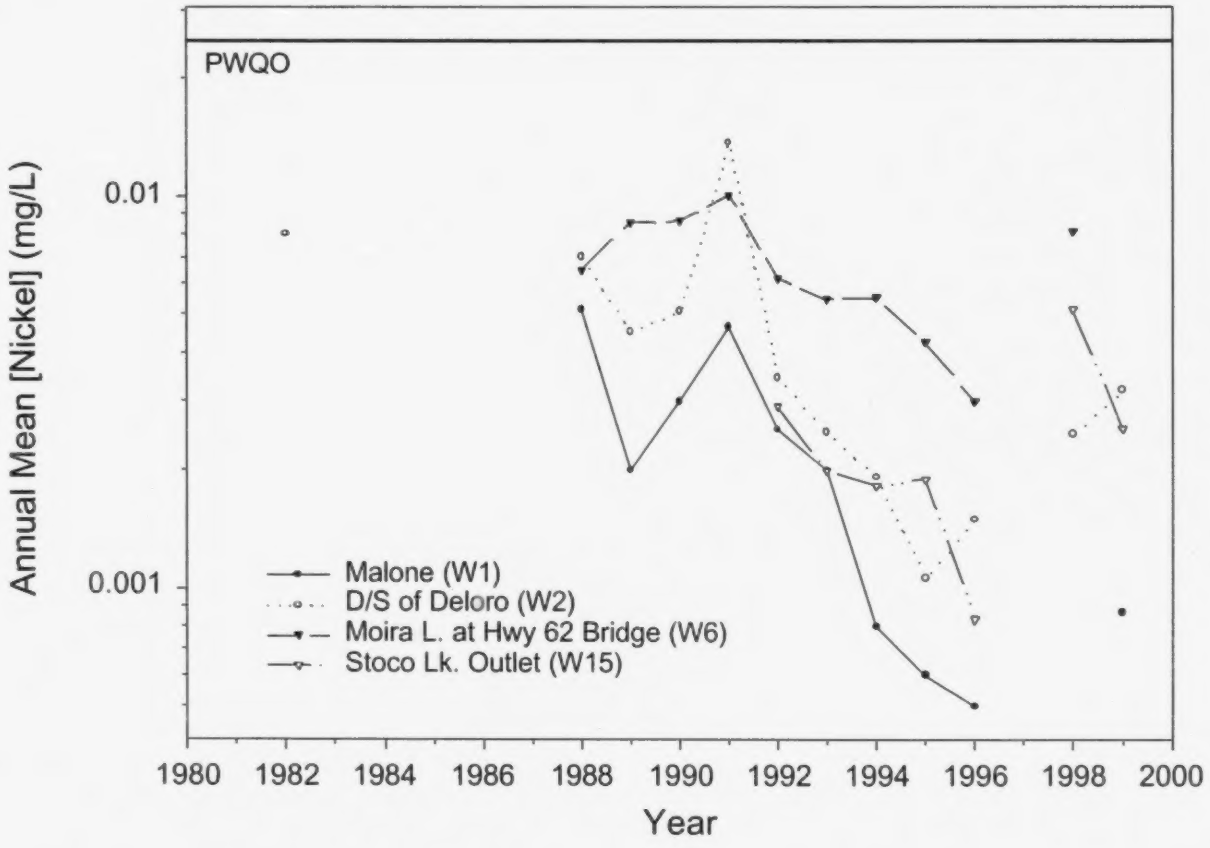


Figure 2.1-7
Annual Mean Moira River Nickel Levels (from Upstream to Downstream) (mg/L)



Changes in Metal Concentrations from 1965 to 1999

Arsenic concentrations in the Moira River have decreased substantially since 1965. Arsenic concentrations decreased by a factor of 10 times at station W2 (just downstream of the Deloro Mine Site) between the mid-1970s and mid-1980s (Figure 2.1-3). This decrease reflects the clean up activities conducted by the MOE at the Deloro Mine Site. These activities included covering of tailings, the installation and operation of a system of wells to capture contaminated groundwater and the construction and operation of a treatment plant to remove arsenic and other metals from groundwater.

Since the mid 1980s, mean annual arsenic concentrations in the river immediately downstream of the site at station W2 have varied from year to year with no apparent trend, although they were always at or below the PWQO (Figure 2.1-3). This variability may be partly in response to variation in river flow. During wetter years when average flows were higher, the concentration of metals, including arsenic, was lower. Conversely during drier years, there was less water available for dilution and the resulting concentrations of metals, including arsenic, were higher. For example, the mean annual flow in 1988 was low (2.62 m^3/sec) near station W2. Arsenic concentrations at station W2 averaged 0.10 mg/L in 1988. In contrast, the mean annual flow in 1995 was 3.68 m^3/sec. Arsenic concentrations at station W2 averaged 0.02 mg/L in 1995. Fluctuation in arsenic concentrations with flow also appear to have occurred upstream of the Deloro Mine Site. For example, arsenic concentrations peaked in the low-flow year 1988 at station W1 near Malone (Figure 2.1-3).

Arsenic concentrations in Moira Lake and Stoco Lake have also declined over time and are now about a factor of 10 below concentrations recorded in the 1960s and 1970s (Station W6 and W15 in Figure 2.1-3). Arsenic concentrations from Stoco Lake to Belleville have also declined by at least a factor of 10 since the 1960s and 1970s (Appendix I). Variability in concentrations since the early 1980s may be related to river flow, as discussed above.

Cobalt concentrations have fluctuated over time, but no consistent trends were observed (Figure 2.1-4). Cobalt was not measured in the 1960s or 1970s; the record begins in 1988. Concentrations have remained consistently above the PWQO in the Deloro-to-Moira Lake section and at or near the PWQO below Moira Lake. Fluctuations appear to be related to flow; however, changes in analytical detection limits are another important factor.

Copper, lead and nickel concentrations appear to have declined with time; however, this may be an artifact of decreasing detection limits (Figures 2.1-2, 2.1-4, 2.1-5, and 2.1-6). Reference site data also show a decline over time (see station W1 in Figures 2.1-4, 2.1-5 and 2.1-6), lending support to the assumption that declining detection limits, rather than any true decrease, are producing the trend observed.

Seasonal Variation

Seasonal variation in metal concentrations was quite pronounced, particularly for arsenic. Peak concentrations occurred from mid-summer through the fall when river flows were lowest. Since the mid-1980's, exceedances of the PWQO only occurred during this mid summer-fall period. This seasonal trend was evident in all of the years of record (1965-1999). It was more pronounced at the stations in the portion of the study area from the Highway 7 bridge to Bend Bay. However, the trend was evident at other stations. Examples of this seasonal variation are given in Figures 2.1-8 to 2.1-11.

Figure 2.1-8
1970 – Seasonal Variability in Arsenic Levels in Moira River at Hwy 7 Bridge (W2)

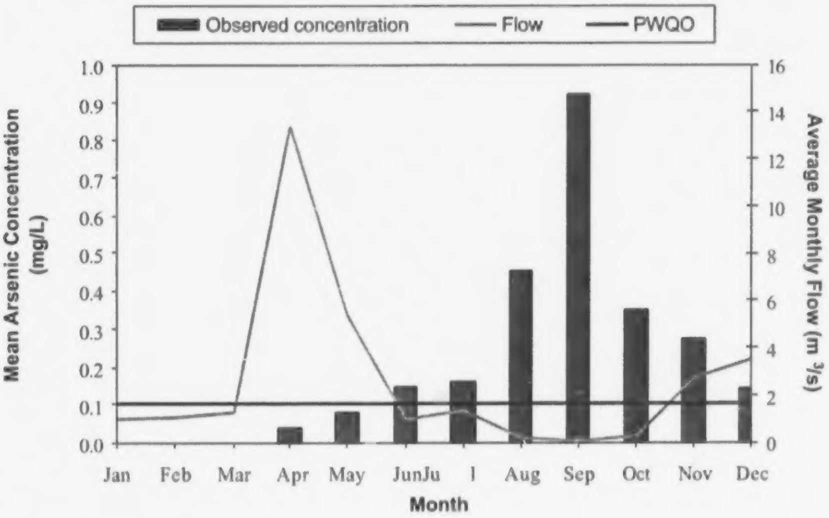


Figure 2.1-9
1980 – Seasonal Variability in Arsenic Levels in Moira River at Hwy 7 Bridge (W2)

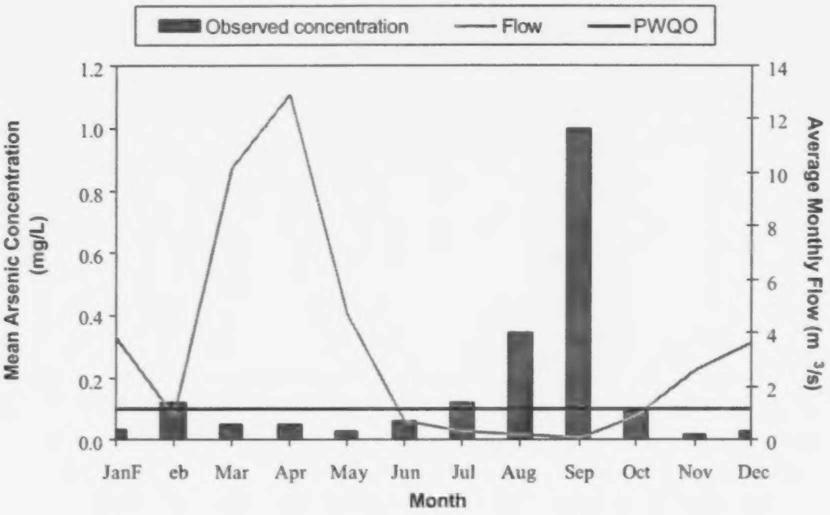


Figure 2.1-10
1990 – Seasonal Variability in Arsenic Levels in Moira River at Hwy 7 Bridge (Site W2)

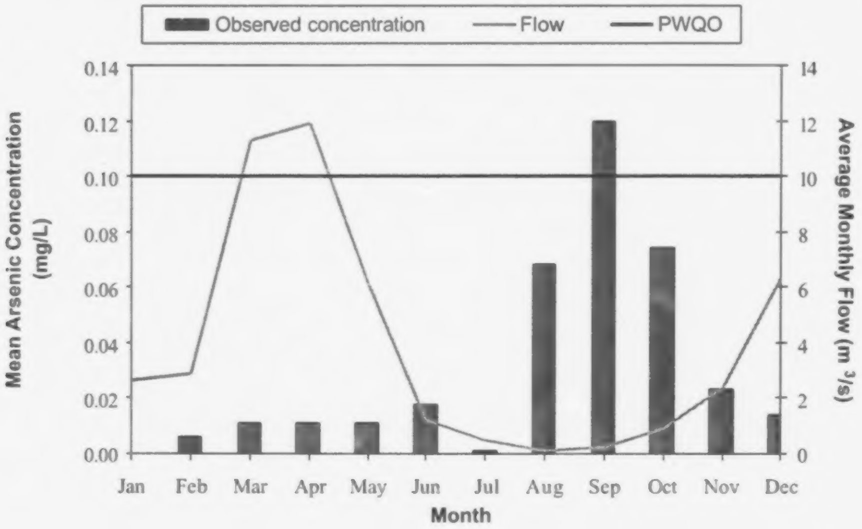
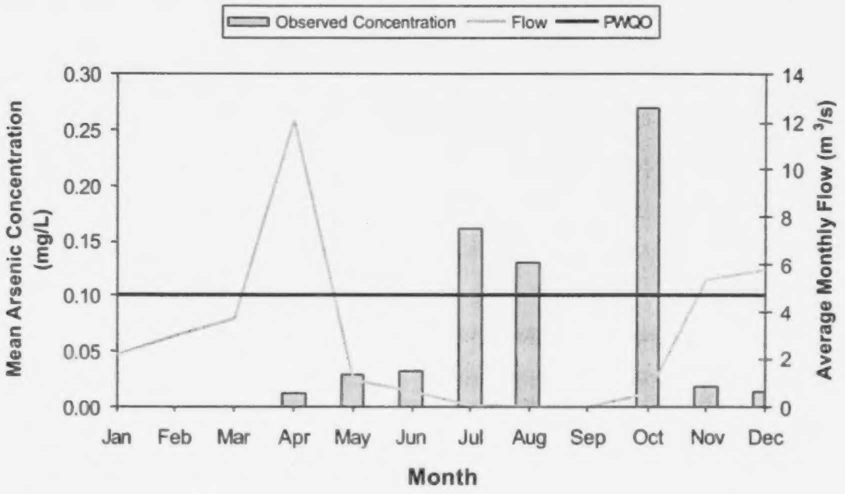


Figure 2.1-11
1999 – Seasonal Variability in Arsenic Levels in Moira River at Hwy 7 Bridge (Site W2)



The concentrations of the other metals of concern also varied seasonally; however, the late summer-early fall peaks were not as pronounced because concentrations were not as elevated (Appendix I). Lead was the only metal of concern that did not have a definite seasonal pattern. The concentrations of lead were the lowest of all of the metals of concern.

There were insufficient data to discuss spatial or temporal trends in silver concentrations. Silver exceeded the PWQO downstream of Stoco Lake during the one time that it was measured (1987).

Temperature and Dissolved Oxygen Profiles

Consecon Lake was the only lake with evidence of temperature stratification; however, oxygen depletion was observed in the deepest portions of Consecon, Moira and Stoco lakes (Appendix I). Dissolved oxygen concentrations fell sharply at depths below the thermocline in Consecon Lake, with anoxic conditions from 11 metres to the bottom of the profile at 16 metres (Appendix I). Although temperature was fairly uniform with depth in Moira Lake, dissolved oxygen concentrations declined below 7 metres and conditions just above the bottom at 9 metres were anoxic (Appendix I). Temperature declined with depth in Stoco Lake, although a definite thermocline was not observed. The greatest change in temperature occurred within 1 metre above the bottom at 8.5 metres. Dissolved oxygen started to decline at 6 metres in Stoco Lake and conditions were anoxic below 8 metres. Temperature and oxygen conditions in Round Lake were fairly uniform with depth. Temperature declined by about 1°C between 1 meter and the bottom of the profile at 8 metres, while dissolved oxygen concentrations ranged from 7.2 to 8.7 mg/L (Appendix I). These results are similar to temperature and oxygen conditions observed in previous monitoring by the MOE, the Ministry of Natural Resources, and the Quinte, Crowe Valley, Cataraqui, Napanee and Lower Trent Conservation Authorities.

The oxygen depletion observed in the deepest portion of three of the four lakes is likely related to oxygen consumption by decomposers in the organic-rich sediments of these lakes. This oxygen depletion will affect metal speciation. Effects on the benthic community and the sentinel fish species of each lake will depend on whether the oxygen depletion is transient within each season, whether it occurs every year, and the spatial extent of the depletion relative to the total area of the lake bottom. This study did not include a detailed examination of oxygen conditions. However, the fact that Round Lake appears to be the only lake without oxygen depletion was a cause for concern with respect to interpretation of differences between reference and exposed populations and communities. Therefore, the overall conclusions for benthic invertebrates and sentinel fish were carefully examined to ensure that they were the same with and without using Round Lake as a reference location.

References

Bowen, G. 1994. Internal Memoranda. Environmental Sciences and Standards Division. Ontario Ministry of the Environment.

Ontario Ministry of Environment and Energy (MOE). Provincial network water quality monitoring (database). 1964 to 1999.

Ontario Ministry of Environment and Energy (MOE). 1999. Water management policies: guidelines provincial water quality objectives. Queen's Printer for Ontario.

SCIMUS. 1999. Deloro Mine Rehabilitation Project: extent and character of radioactive materials. Prepared for Ontario Ministry of the Environment by SCIMUS Inc., Toronto Ontario.

2.2 Sediments

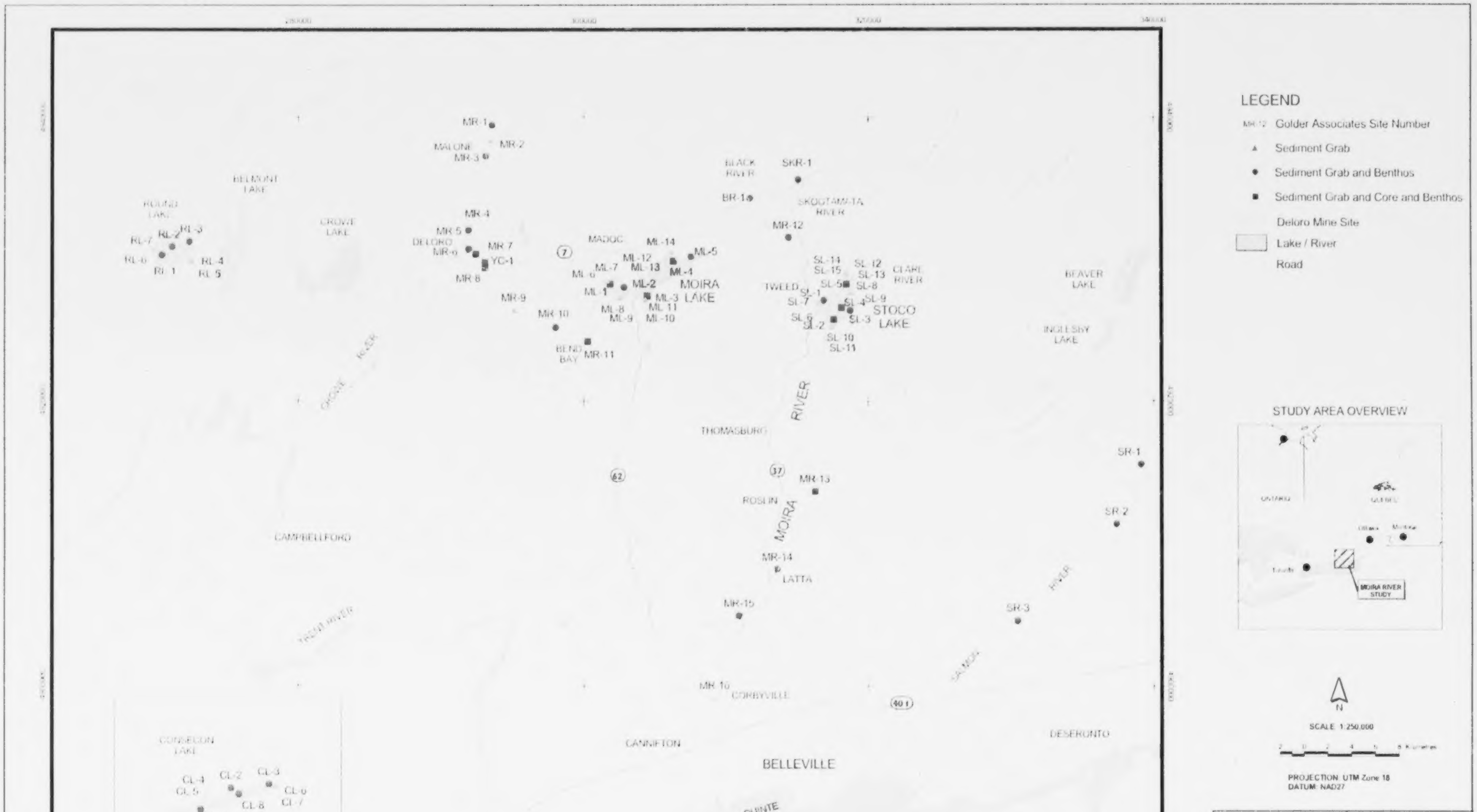
2.2.1 Methods

Sediment quality data were obtained from the Ministry of Environment (MOE) In-Place Pollutants Program. Sediment grab samples were collected in the spring of 1999 from 66 locations as identified in Figure 2.2-1 and Table 2.2-1.

Most locations were selected as representative of the deeper areas of sediment accumulation within the lakes and Moira River. In addition, some grab samples were collected in near-shore beach areas in the lakes. The metal concentrations from these beach locations plus data from the shallower river stations (<1 m) were considered in the exposure assessment conducted for the Preliminary Quantitative Risk Assessment (PQRA) reported in Chapter 3 of this study.

The Moira River above the inlet of Moira Lake is generally fast flowing and characterized by a rocky substrate. Areas of sediment accumulation are localized and where observed, consist of fine-grained materials deposited in shallow backwater areas. In general, these areas of sediment accumulation are not attractive to recreational users because of the fine-mud nature of the bottom and the relatively shallow depth of the water. Sandy beach areas were not noted and only a few cottages were observed in this section of the river during the sediment sampling field program. Ready public access to this section of the river is limited to road crossings at Highway 7 and the Old Marmora Road in the vicinity of Deloro. Therefore, there is limited opportunity for exposure by local residents to shallow-water sediments in this area of the Moira River.

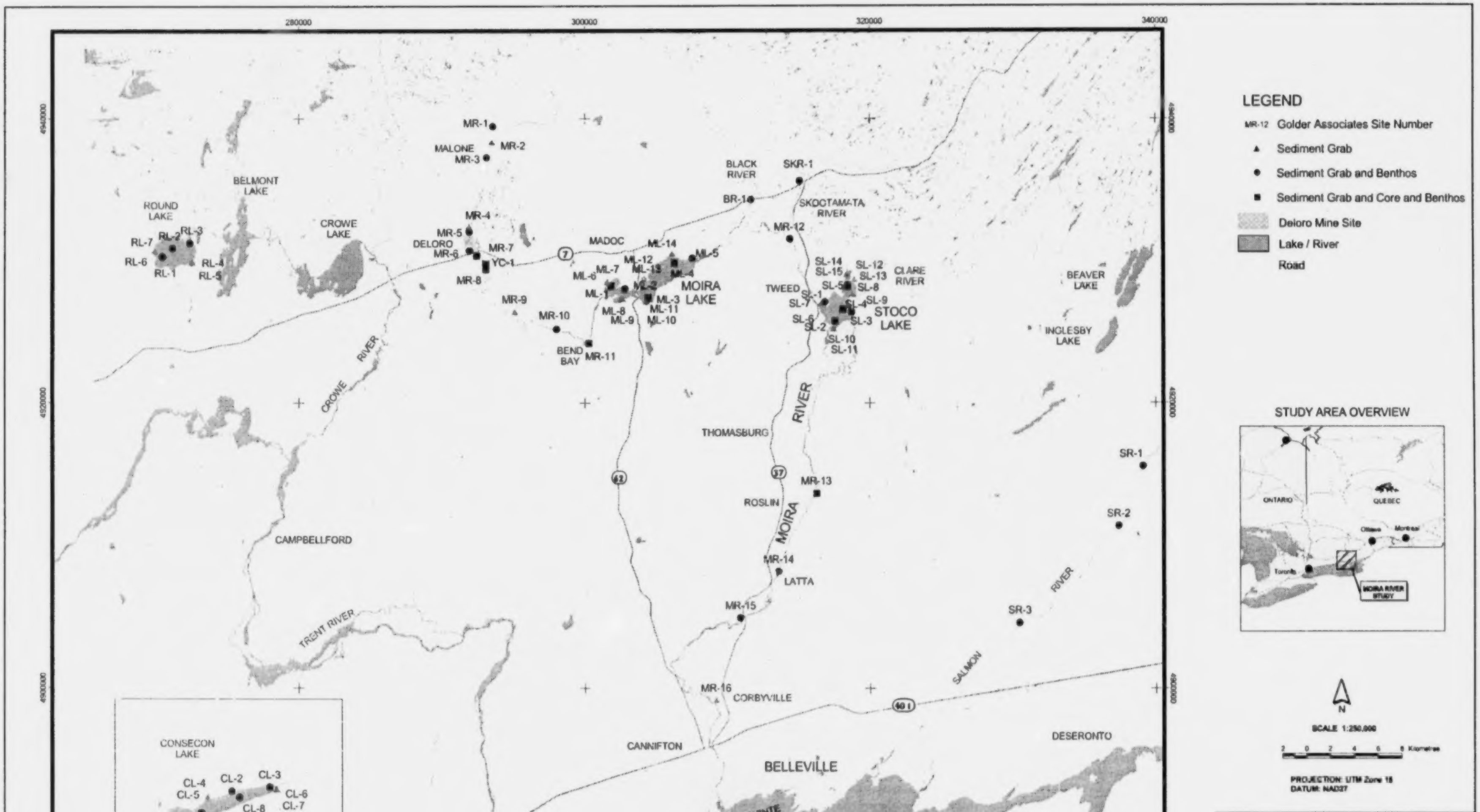
Young's Creek, which joins the Moira River just below Highway 7, contains a significant volume of sediments that have accumulated behind a series of beaver dams. North of Highway 7, these sediments are known to include radioactive tailings as identified during the assessment of the Deloro Mine Site (SCIMUS 1999). The sediments south of Highway 7 were also expected to contain metals derived from the Deloro Mine Site; however, radionuclide content may be low because SCIMUS (1999) found that radioactivity declined to background levels upstream of Highway 7.


LEGEND
MR-12 Golder Associates Site Number
▲ Sediment Grab
● Sediment Grab and Benthos
■ Sediment Grab and Core and Benthos
Deloro Mine Site
Lake / River
Road
STUDY AREA OVERVIEW
ONTARIO
QUEBEC
Ottawa
Montreal
Toronto
MOIRA RIVER STUDY
N
SCALE 1:250,000
2 0 2 4 6 8 Kilometres
PROJECTION: UTM Zone 18
DATUM: NAD27
280000
300000
320000
340000
MR-1
MALONE
MR-2
MR-3
BELMONT LAKE
ROUND LAKE
RL-3
RL-2
RL-7
RL-6
RL-1
RL-4
RL-5
CROWE LAKE
MR-4
MR-5
DELORO
MR-6
MR 7
YC-1
MR 8
MR-9
MR 10
BEND BAY
MR-11
MADOC
7
ML-14
ML-5
ML-12
ML-13
ML-4
ML-6
ML-7
ML-2
ML-1
ML-8
ML-9
ML-3
ML-11
ML-10
MOIRA LAKE
BLACK RIVER
SKR-1
BR-1
SKOOTAMATA RIVER
MR-12
SL-14
SL-15
SL-12
SL-13
CLARE RIVER
SL-5
SL-8
TWEED
SL-1
SL-7
SL-4
SL-9
SL-6
SL-2
SL-3
STOCO LAKE
SL-10
SL-11
BEAVER LAKE
INGLESBY LAKE
CROWE RIVER
RIVER
THOMASBURG
62
37
MR-13
ROSLIN
MOIRA
MR-14
LATTA
MR-15
CAMPBELLFORD
TRENT RIVER
SR-1
SR 2
SR-3
SALMON RIVER
MR-16
CORBYVILLE
401
DESERONTO
CANNIFTON
BELLEVILLE
BAY OF QUINTE
CONSECON LAKE
CL-4
CL-5
CL-2
CL-3
CL-6
CL-7
CL-8
CL-1
Note: Consecon Lake is 18 kilometers south of Belleville

Golder Associates

MOIRA RIVER STUDY
1999 SEDIMENT QUALITY
SAMPLE LOCATIONS

10 APRIL 2000	Figure 2.2-1	CHECKED BY: BW REVIEWED BY: RR


280000
300000
320000
340000
4940000
4920000
4900000
LEGEND
MR-12 Golder Associates Site Number
▲ Sediment Grab
● Sediment Grab and Benthos
■ Sediment Grab and Core and Benthos
▨ Deloro Mine Site
▨ Lake / River
Road
MR-1
MALONE
MR-2
MR-3
BLACK RIVER
SKR-1
BR-1
SKOOTAMATA RIVER
MR-12
ROUND LAKE
BELMONT LAKE
CROWE LAKE
RL-7
RL-2
RL-3
RL-6
RL-1
RL-4
RL-5
MR-4
MR-5
DELORO
MR-6
MR-7
YC-1
MR-8
7
MADOC
ML-14
ML-12
ML-13
ML-5
ML-4
ML-6
ML-7
ML-1
ML-2
ML-3
ML-11
ML-10
ML-8
ML-9
MOIRA LAKE
MR-9
MR-10
BEND BAY
MR-11
SL-14
SL-15
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SL-13
SL-5
SL-8
CLARE RIVER
TWEED
SL-1
SL-7
SL-4
SL-9
SL-6
SL-2
SL-3
STOCO LAKE
SL-10
SL-11
BEAVER LAKE
INGLESBY LAKE
CROWE RIVER
RIVER
THOMASBURG
37
MR-13
42
ROSLIN
MOIRA
CAMPBELLFORD
MR-14
LATTA
MR-15
TRENT RIVER
SR-1
SR-2
SR-3
RIVER
SALMON
MR-16
CORBYVILLE
401
CANNIFTON
BELLEVILLE
DESERONTO
BAY
OF
QUINTE
CONSECON LAKE
CL-4
CL-5
CL-2
CL-3
CL-6
CL-7
CL-8
CL-1
Note: Consecon Lake is 18 kilometers south of Belleville
STUDY AREA OVERVIEW
ONTARIO
QUEBEC
Ottawa
Montreal
Toronto
MOIRA RIVER STUDY
N
SCALE 1:250,000
2 0 2 4 6 8 Kilometres
PROJECTION: UTM Zone 18
DATUM: NAD27

Golder Associates

MOIRA RIVER STUDY
1999 SEDIMENT QUALITY
SAMPLE LOCATIONS

10 APRIL 2000	Figure 2.2-1	PRODUCED BY: BW REVIEWED BY: RR

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Table 2.2-1
Identification and Description of Sediment Core and Grab Stations

Sediment Quality Stations		
MOE Station Number	**General Name Used in This Study**	**Description**
M1	MR-3*	Moira River downstream of Malone
M2	MR-1*	Moira River upstream of Malone
M3	MR-5	Moira River at the Deloro Mine Site
M4	MR-6*	Moira River just downstream of Deloro near Highway 7
M5	MR-7*	Moira River at Highway 7
M6	MR-8*	Moira River just downstream of Young's Creek (Grab & Core Samples Collected)
M7	MR-9*	Moira River upstream of Bend Bay(Grab & Core Samples Collected)
M8	MR-10*	Moira River upstream of Bend Bay
M9	MR-11	Moira River at Bend Bay (Grab & Core Samples Collected)
M10	MR-12	Moira River downstream of the Skootamatta
M11	MR-14	Moira River near Latta
M12	MR-13	Moira River near Roslin (grab & core samples collected)
M13	ML-1*	Moira Lake Inlet (grab & core samples collected)
M14	ML-2	Moira Lake. Mid-basin
M15	ML-3	Moira Lake Mid-basin (grab & core samples collected)
M16	ML-4*	Moira Lake Outlet (grab & core samples collected)
M17	ML-5*	Moira Lake Outlet
M18	ML-6	Moira Lake near-shore near inlet at 1 meter depth
M19	ML-7	Moira Lake near-shore near inlet at 2 meter depth
M20	ML-8	Moira Lake near-shore on south shore west of Highway 62 at 1 m
M21	ML-9	Moira Lake near-shore on south shore west of Highway 62 at 2 m
M22	ML-10	Moira Lake near-shore on south shore east of Highway 62 at 1 m
M23	ML-11	Moira Lake near-shore on south shore east of Highway 62 at 2 m
M24	ML-12	Moira Lake near-shore on north shore at 1 m
M25	ML-13	Moira Lake near-shore on north shore at 2 m
M26	ML-14	Moira Lake near-shore on north shore
M27	SL-1*	Stoco Lake Inlet
M28	SL-2	Stoco Lake Outlet (grab & core samples collected)
M29	SL-3*	Stoco Lake Mid-Basin
M30	SL-4*	Stoco Lake Mid-basin (grab & core samples collected)
M31	SL-5	Stoco Lake North (grab & core samples collected)
M32	SL-6	Stoco Lake near-shore near inlet at 1 m
M33	SL-7	Stoco Lake near-shore near inlet at 2 m
M34	SL-8	Stoco Lake near-shore on northeast shore at 1 m
M35	SL-9	Stoco Lake near-shore on northeast shore at 2 m
M36	SL-10	Stoco Lake near-shore on south shore at 1 m
M37	SL-11	Stoco Lake near-shore on south shore at 2 m
M38	SL-12	Stoco Lake near-shore on north shore of north arm at 1 m
M39	SL-13	Stoco Lake near-shore on north shore of north arm at 2 m
M40	SL-14	Stoco Lake near-shore northwest shore of north arm at 1 m

Sediment Quality Stations		
MOE Station Number	General Name Used in This Study	Description
M41	SL-15	Stoco Lake near-shore northwest shore of north arm at 2 m
M42	MR-15	Moira River at Highway 37
M43	RL-1*	Round Lake inlet
M44	RL-2*	Round Lake mid-basin
M45	RL-3*	Round Lake outlet
M46	RL-4	Round Lake near-shore on southeast shore at 1 m
M47	RL-5	Round Lake near-shore on southeast shore at 2 m
M48	RL-6	Round Lake near-shore on west shore near inlet at 1 m
M49	RL-7	Round Lake near-shore on west shore near inlet at 2 m
M50	CL-1*	Consecon Lake near inlet
M51	CL-2*	Consecon Lake mid-basin
M52	CL-3*	Consecon Lake near outlet
M53	CL-4	Consecon Lake near-shore on north shore at 1 m
M54	CL-5	Consecon Lake near-shore on north shore at 2 m
M55	CL-6	Consecon Lake near-shore on east end near outlet at 1 m
M56	CL-7	Consecon Lake near-shore on east end near outlet at 2 m
M57	BR-1*	Black River
M58	SKR-1*	Skootamatta River
M59	MR-4*	Moira River at the Deloro Mine Site
M60	MR-16	Moira River near Corbyville
M61	YC-1*	Young's Creek (Grab & Core Samples Collected)
M62	CL-8*	Consecon Lake deep basin below thermocline
M63	SR-1*	Salmon River
M64	SR-2*	Salmon River
M65	SR-3*	Salmon River
M66	MR-2	Moira River at Malone

* Grab samples were also submitted for sediment toxicity testing.

Sediment core samples were collected in August of 1999 at 11 locations that overlap with 11 of the sediment grab stations (Figure 2.2-1 and Table 2.2-1). Sediment core samples were kept cool, but not frozen and shipped to Philip Analytical Services Corporation for analysis. Sediment grab samples were analyzed by the MOE for metals, major nutrients and particle sizes. MOE Standard Reference Methods for sediment samples were used to analyze metals (Appendix II). MOE identifies their standard method procedures with an identification code for each analysis. Inductive coupled plasma (ICP) was used for the analysis of trace metals in sediments (Reference I.D. - E3062A). The hydride metals such as arsenic was analyzed with atomic absorption (AA) hydride generation (Reference I.D. - E3245A). Mercury was analyzed with cold vapour AA (Reference I.D. – E3059A). Finally, uranium concentrations in sediment were analyzed with an ICP mass spectrometer instrument. Through-out the chemical analysis, a

15-20% quality control (QC) program consisting of NIST (National Institute of Standards and Technology) standards, duplicates, blanks and controls was used. MOE verifies all QC samples to authorize the accuracy and precision of the analytical instruments and, thus, the reliability of results.

The top 0-5 cm portion of the sediment core samples was analyzed by Philip Analytical Services for metals using a sequential extraction (Tessier *et al.* 1979). The sequential extraction procedure partitions metals into five fractions that correspond to binding of metals to different substances within the sediments. The five fractions, in order of increasingly tight bonds to substrates are:

- Exchangeable metals:
    - Extracted with either magnesium chloride or sodium acetate.
    - This fraction represents metals that are most likely to desorb and re-enter the water column.
- Metals bound to carbonates:
    - Leached with sodium acetate adjusted to pH 5 with continuous agitation.
    - This fraction represents metals that desorb with changes in pH.
- Metals bound to organic matter:
    - Extracted with nitric acid and peroxide plus ammonium acetate to prevent adsorption of extracted metals.
    - This fraction represents metals bound to various forms of organic matter such as living organisms, dead and decaying organisms, coatings on mineral particles, etc. Under oxidizing conditions, organic matter can be degraded, leading to release of soluble metals.
    - It should be noted that the organic fraction also includes sulphides, which also release metals if redox conditions are altered.
- Metals bound to iron and manganese:
    - Extracted with either sodium citrate or ammonium hydroxide.
    - Metals bound to iron or manganese oxides will be released under anoxic conditions.

- Residual metals:
    - Digested with hydrofluoric and perchloric acids.
    - This fraction represents metals bound in primary and secondary minerals, held within the crystal structure. These metals are not expected to be released into solution under conditions normally encountered in nature.

The information on the fractions of metals in the top five centimetres of sediment provided an indication of the relative bioavailability of metals in the Moira River system. For example, metals in the "exchangeable" and "carbonates" fractions are more readily released back into solution; therefore, these fractions can be assumed to be more available for uptake by aquatic biota. In contrast, metals in the "iron and manganese oxides" fraction are released only under anoxic conditions; therefore, metals in this fraction are not as available for uptake by aquatic biota in oxygenated conditions. Metals in the "residual" fraction can be assumed to be unavailable for uptake by aquatic biota. That the sequential extraction method used is not specific for sulphide-bound metals (instead, they are represented within the organic fraction). More recent studies have shown that the toxicity of some metals in sediments (notably cadmium, copper, lead, nickel, and zinc) can be reliably predicted using metal-sulphide relationships and/or pore-water metal concentrations (Ankley *et al* 1996). Acid-volatile sulphide concentrations were not measured in this study.

The 5-10, 10-20 and 20-30 cm portions of the cores were analyzed for total metals (Powell, pers. comm). The core sections were also analyzed for total organic carbon and particle size.

In 1998 and 1999, sediment samples from various stations in the Moira River system were collected and submitted to the Ministry of Labour, Radiation Protection Monitoring Service for radionuclide analysis. During the spring of 1999, 64 sediment samples were collected by MOE from the locations identified in Figure 2.2-1 for analysis of the following:

- Moisture;
- Radium-226;
- Radium-228;
- Thorium-228; and
- Uranium-238.

Samples were counted by gamma spectrometry using high purity Germanium detectors for 10,000 seconds each. Appendix II provides additional details on QA/QC, calibration of gamma detectors and determination of gamma emitters taken by the Radiation Protection Laboratory.

Field techniques were the standard MOE practices (Jaagumagi, pers. comm.). Sediment grab samples were sub-samples of three individual replicates that were mixed with a stainless steel spoon in a mixing bowl until an even colour and consistency were observed. The sediment core samples were processed similarly, except samples were composed of 4 to 5 individual replicates. The sediment grab samples taken from lakes were collected with a standard, full-size Ponar grab. Grab samples from river stations were collected with a 9" × 9" × 12" stainless steel Ekman grab. Sediment core samples were collected with a stainless steel K-B Corer (Wildco) fitted with 2" plexiglas or a Benthos Gravity corer (custom-made) fitted with 3" plexi tubes. The sampling instruments, mixing bowls, and sampling handling gear were cleaned with lake or river water between each sample. Any residue was scrubbed off the device with a brush, and the device was then rinsed thoroughly.

Sample containers were provided by MOE and pre-cleaned using MOE standard practices (Powell, pers. comm.). There was no preservation required for sediment samples. At all times during the field-sampling program, field notes were maintained, and photos were taken at nearly every site sampled. All samples were labelled with the project name, station number, collection date and kept in a cooler for transport to a refrigerator at 4 degrees C until submission to the laboratory. No field or travel blanks were collected during the sediment sampling program. Sampling stations were located with a hand held GPS instrument, and samples were collected from areas were there was a suitable volume of soft sediments for analysis.

2.2.2 Identification of Metals of Concern

The same metals of concern determined for water quality were used for sediment quality; however, uranium was added to the list because of the potential for migration of uranium from the "red mud tailings" at the Deloro Mine Site. Therefore, the metals of concern for sediments were:

- Arsenic
- Cobalt

- Copper
- Lead
- Nickel
- Silver
- Uranium.

Uranium is both a metal and a radionuclide. The "daughter products" produced by the radioactive decay of uranium (such as radium-226) are not as mobile in the environment as uranium. This was confirmed by the very low levels of radium-226 found in sediments collected for this study.

With the exception of uranium, radionuclide concentrations in reference sediments as well as downstream sediments, were consistently low. Radium-226, radium-228 and thorium-228 activities were less than or equal to detection limits at all stations, with the exception of one sample from Round Lake, one sample from Stoco Lake and Young's Creek (Appendix II). The Round Lake and Stoco Lake samples contained 0.02 Bq/g radium-226 (detection limit is 0.01 Bq/g). The Young's Creek station had 0.05 Bq/g radium-226.

2.2.3 Application of Ontario Sediment Quality Guidelines for Metals

The metal concentrations observed in the sediments from the Moira River system were compared to Provincial Sediment Quality Guidelines (PSQGs). Four out of the seven metals of concern have PSQGs (Table 2.2-2). The comparison with guidelines served as one indication of the potential for toxicity to aquatic biota. The MOE Guidelines (1993) state that if metal concentrations exceed the Lowest Effect Level (LEL), then there may be adverse effects on some aquatic biota. If metal concentrations exceed the Severe Effects Level (SEL), then there may be significant effects on aquatic biota.

As noted in Section 1, the PSQGs were developed for the protection of aquatic life. The PSQGs are used to indicate the need for additional biological testing and field assessment of the benthic invertebrate community. They are not meant to trigger remedial action. In the case of this study, sediment toxicity testing and benthic invertebrate community assessments were already part of the study design. Therefore, the sediment chemistry data were one component of a three-component assessment of the effects of the metal concentrations observed in the Moira River system.

Table 2.2-2
Provincial Sediment Quality Guidelines

Metal	Lowest Effect Level (μg/g)	Severe Effect Level (μg/g)
Arsenic	6	33
Copper	16	110
Lead	31	250
Nickel	16	75

Cobalt, uranium and silver do not have PSQGs. Screening Level Concentrations (SLCs) were derived for cobalt and silver according to the methods outlined in MOE (1993). An SLC for uranium could not be derived because the dataset was too small.

The site-specific development of SLCs is an effects-based approach that is used to develop sediment quality guidelines that are protective of benthic organisms. Guidelines are developed from the co-occurrence of benthic fauna and a wide range of chemical concentrations. The SLC is an estimate of the highest concentration of a metal that can be tolerated by 95% of the benthic fauna observed from the sampling locations.

The SLC was developed through a three-step process incorporating species from lake and river sites. From the list of benthic fauna recorded (Rivers: 117, Lakes: 68) in field investigations, a list of species (at least 10) that were present at 10 or more sites was compiled. For each species, the associated metal concentrations were found for each site where the species was present and the 90th percentile was determined. This represented the species screening level concentration (SSLC) that 90% of the population appeared to tolerate based on field data. The top 10% was removed from further analysis to produce a more conservative estimate and eliminate extreme sediment concentrations that may be a result of physical and/or chemical sediment characteristics. The SSLC was determined for each metal and species and plotted to determine the 5th percentile. This represented the screening level concentration (SLC) which 95% of the species found in the Moira River system and reference locations could tolerate.

Screening level concentrations were determined for lake and river communities combined. This approach was considered the most conservative. The SLC guidelines for lake and river sediments combined are presented in Table 2.2-3.

The SLCs for cobalt and silver were derived from a limited data set. Therefore, they are only applicable to the Moira River system and cannot be considered analogous to PSQGs.

Table 2.2-3
Screening Level Concentrations (SLC) for Lakes and Rivers (µg/g)

Guideline	Cobalt	Silver
SLC for lakes & rivers combined	296	5.1

Interpretation of exceedances of the SLCs is the same as for exceedances of the PSQGs; i.e., they serve as one indicator of the potential for adverse effects on benthic invertebrates. They cannot be used as "triggers" for remedial action in the Moira River system.

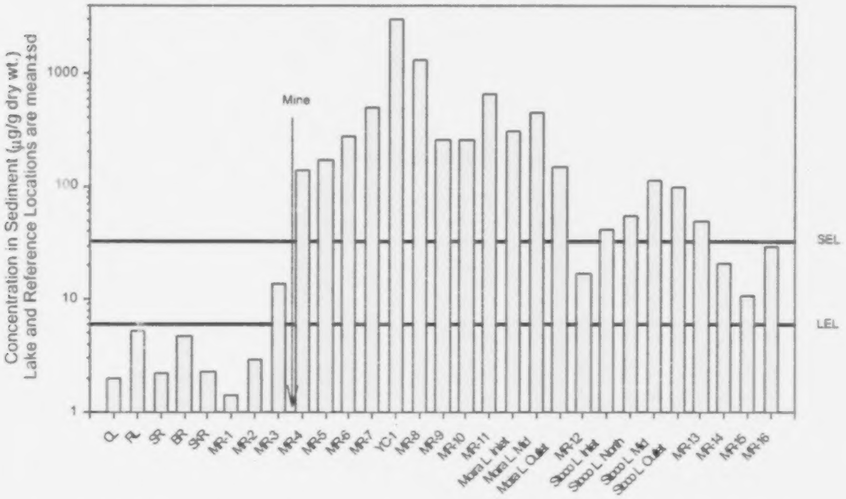
Uranium concentrations in sediments downstream of the Deloro Mine Site were compared to reference concentrations at reference sites (upstream of the Deloro Mine Site, Black River, Skootamatta River, Salmon River, Round and Consecon lakes).

2.2.4 Results and Discussion

2.2.4.1 Sediment Grab Samples

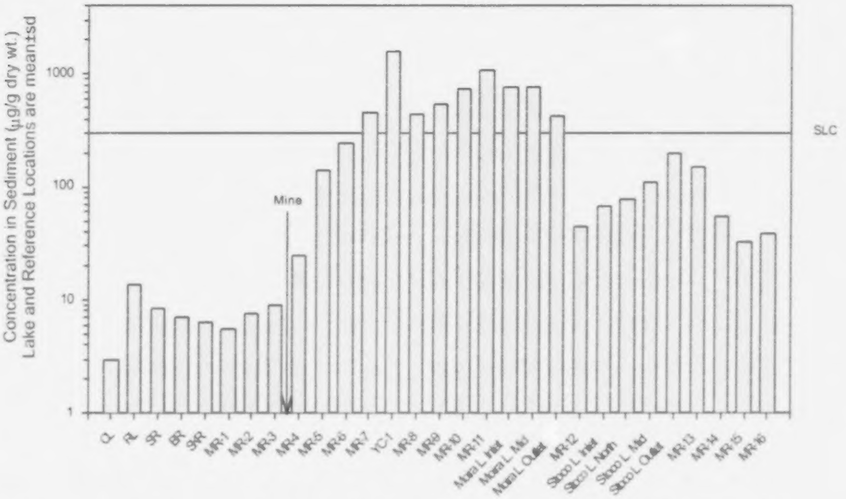
Metal concentrations in all sediment grab samples from reference sites were consistently low compared to the Moira River system from the Deloro Mine Site to the Moira Lake outlet. This was true in the lakes (Consecon and Round lakes) and the rivers (Salmon, Black and Skootamatta rivers) (Figures 2.2-2 to 2.2-7). Arsenic concentrations were below LELs at all reference locations except in the Moira River system downstream of Malone (MR-3). Copper, lead and nickel concentrations exceeded LELs in Round Lake and the Skootamatta River. Reference concentrations of all the metals of concern were similar to concentrations reported from other Ontario reference locations (Mason and Dragun 1996).

Figure 2.2-2
Total Arsenic in Bottom Sediment Grab Samples (Excluding Near-Shore) – Moira River Watershed and Reference Sites, 1999[1]



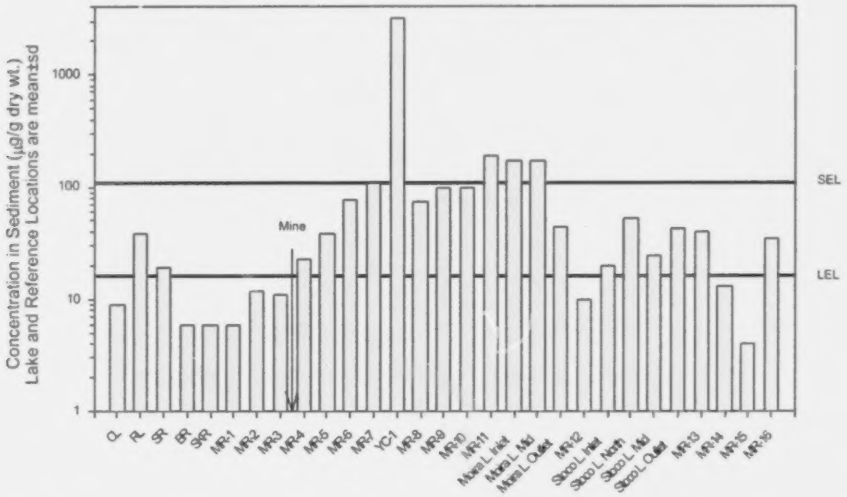
Horizontal lines indicate Severe and Lowest Effect Level from Ontario Sediment Quality Guidelines.
[1] Reference lake and mid-basin Moira Lake and Stoco Lake results are averages of two or more stations.

Figure 2.2-3
Total Cobalt in Bottom Sediment Grab Samples (Excluding Near-Shore) – Moira River Watershed, 1999[1]



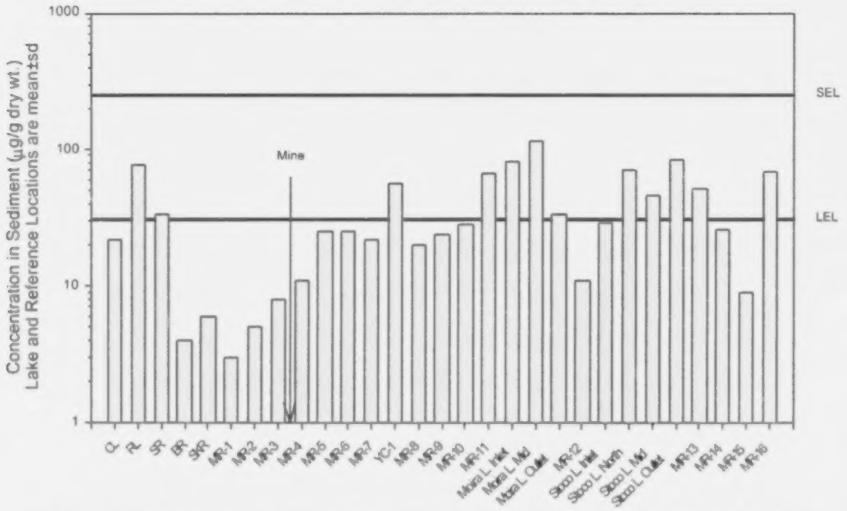
Horizontal lines indicate Severe and Lowest Effect Level from Ontario Sediment Quality Guidelines.
[1] Reference lake and mid-basin Moira Lake and Stoco Lake results are averages of two or more stations.

Figure 2.2-4
Total Copper in Bottom Sediment Grab Samples (Excluding Near-Shore) – Moira River Watershed, 1999[1]



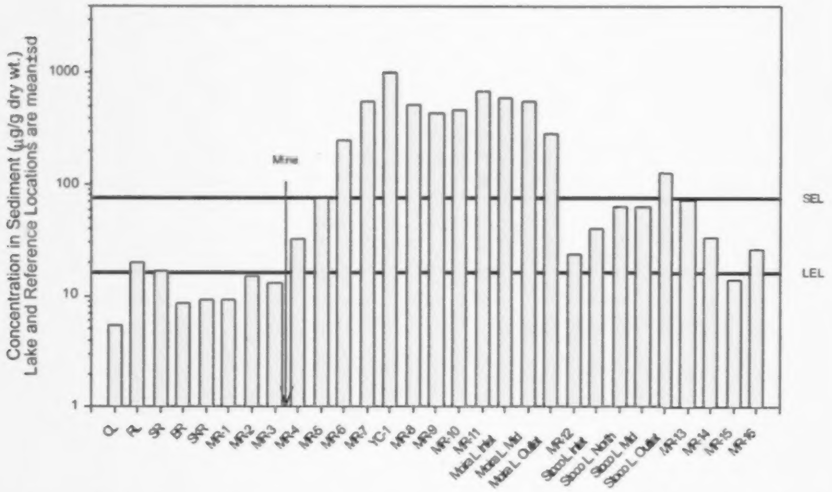
Horizontal lines indicate Severe and Lowest Effect Level from Ontario Sediment Quality Guidelines.
[1] Reference lake and mid-basin Moira Lake and Stoco Lake results are averages of two or more stations.

Figure 2.2-5
Total Lead in Bottom Sediment Grab Samples (Excluding Near-Shore) – Moira River Watershed, 1999[1]



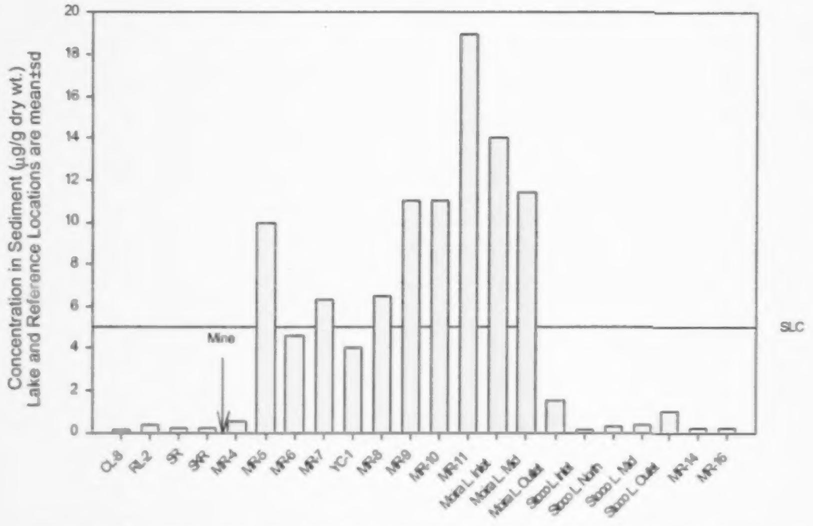
Horizontal lines indicate Severe and Lowest Effect Level from Ontario Sediment Quality Guidelines.
[1] Reference lake and mid-basin Moira Lake and Stoco Lake results are averages of two or more stations

Figure 2.2-6
Total Nickel in Bottom Sediment Grab Samples (Excluding Near-Shore) – Moira River Watershed, 1999[1]



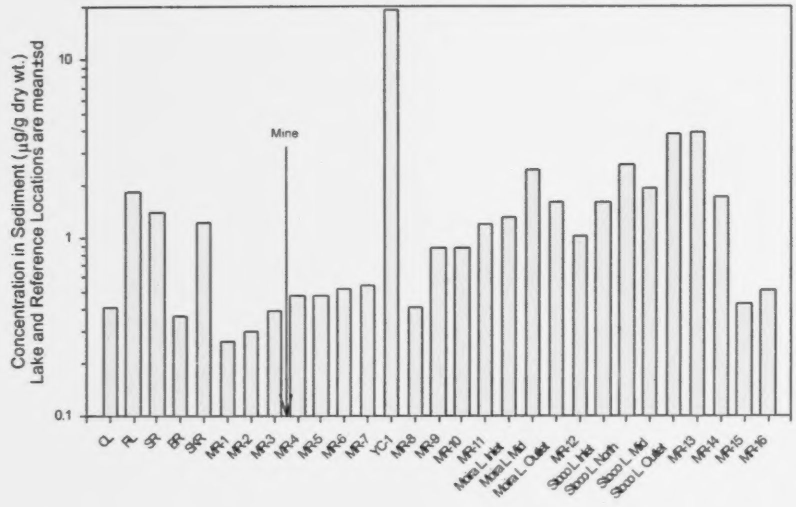
Horizontal lines indicate Severe and Lowest Effect Level from Ontario Sediment Quality Guidelines.
[1] Reference lake and mid-basin Moira Lake and Stoco Lake results are averages of two or more stations.

Figure 2.2-7
Total Silver in Bottom Sediment Grab Samples (Excluding Near-Shore) – Moira River Watershed, 1999[1]



Horizontal lines indicate Severe and Lowest Effect Level from Ontario Sediment Quality Guidelines.
[1] Reference lake and mid-basin Moira Lake and Stoco Lake results are averages of two or more stations.

Figure 2.2-8
Total Uranium in Bottom Sediment Grab Samples (Excluding Near-Shore) – Moira River Watershed, 1999[1]



[1] Reference lake and mid-basin Moira Lake and Stoco Lake results are averages of two or more stations.

Metal concentrations from the three reference sites upstream of the Deloro Mine Site in the Moira River were similar to the other reference concentrations, except for arsenic, lead and uranium. Arsenic concentrations at the upstream station closest to Deloro (MR-3) were higher than at any of the other reference sites (Figure 2.2-2). Lead concentrations at all of the upstream stations were lower than lead concentrations found in the reference lakes and the Salmon River (Figure 2.2-5). Uranium concentrations at all of the upstream stations were lower than uranium concentrations found in Round Lake, the Salmon River and the Skootamatta River (Figure 2.2-8).

Metal concentrations in sediment grab samples followed a fairly consistent trend from upstream-to-downstream in the Moira River system (Figures 2.2-2 to 2.2-8). A substantial increase usually occurred downstream of the Deloro Mine Site, followed by an additional increase downstream of the confluence with Young's Creek. The highest concentrations were observed in the one sediment sample collected from Young's Creek (YC-1). Metal concentrations then gradually declined, with the most substantial drop occurring after the Moira Lake outlet. Arsenic, cobalt and nickel concentrations remained elevated above reference values all the way to the farthest downstream station (MR-16: near Corbyville). Copper, lead and uranium concentrations fluctuated after the outlet of Moira Lake, but on the whole were more similar to reference concentrations than to the concentrations in the Deloro-to-Moira Lake section of the system.

Some of the fluctuations in metal concentrations from site-to-site may be related to differences in total organic carbon (TOC) or particle size, since both of these parameters are often correlated with total metal content in sediments (Håkanson 1992, Mahony *et al.* 1996). For example, Round Lake sediments (excluding beach samples) had higher TOC concentrations than in Consecon Lake (Appendix II, page II-3). Metal concentrations in Round Lake sediments were usually higher than in Consecon Lake (Figures 2.2-2 to 2.2-8), which may reflect a higher metal-binding capacity in Round Lake sediments because of the higher organic content. Moira Lake sediments had higher TOC concentrations than Stoco Lake sediments (Appendix II, page II-3). Therefore, part of the explanation for lower metal concentrations in Stoco Lake may be a lower metal-binding capacity. The relationship between TOC and metal concentration was confirmed during statistical analyses in support of the interpretation of benthic invertebrate data (see Tables 2.3-5 and 2.3-13). Particle size did not differ consistently among sites (Appendix II, page II-7), and few statistical relationships were found between particle size and metal concentrations (see Section 2.3). The exception to this would be in the coarser-grained beach samples (see discussion below).

The SELs or SLCs for the metals of concern were usually exceeded at the stations from Highway 7 (Station MR-7) through to Moira Lake. The arsenic and nickel SELs were exceeded in the sediment grab samples from Highway 7 to the Moira Lake outlet (Figures 2.2-2, 2.2-4 and 2.2-6). Arsenic and nickel also exceeded the SEL at some locations in Stoco Lake. Copper exceeded the SEL at Young's Creek and in three stations within Moira Lake. The cobalt SLC was exceeded from Highway 7 to the Moira Lake outlet (Figure 2.2-3). Silver usually exceeded the SLC at stations from Highway 7 to mid-basin of Moira Lake (Figure 2.2-7).

The pattern of lead concentrations relative to the PSQG was different from all of the other metals of concern (Figure 2.2-5). The lead SEL was not exceeded at any location. Although lead concentrations downstream of the Deloro Mine Site were greater than upstream of the site, concentrations far downstream (e.g., at Corbyville) were similar to concentrations in Round Lake and the Skootamatta River. Therefore, lead in sediments may reflect other sources (such as local geology or inputs from leaded gasoline).

Uranium concentrations in the sediments of Young's Creek, mid-basin Moira Lake, Stoco Lake North, Stoco Lake outlet and Moira River near Roslin were higher than reference concentrations (Figure 2.2-8). This shows that some historical migration of uranium has occurred. The Young's Creek sediments have the highest concentrations, as would be expected given their proximity to the "red mud tailings" source at the Deloro Mine Site. The uranium concentrations in the lake basin sediments and in the Moira River near Roslin were only slightly elevated above concentrations found in Round Lake (one of the reference lakes), and may simply reflect the natural variability of uranium concentrations in the study area.

The results of the two methods used to measure uranium in the sediment grab samples were compared to ensure that the results were in reasonable agreement. Uranium was measured as a metal in µg/g using ICP-MS analysis, and as a radionuclide in Bq/g using gamma spectroscopy (Appendix II). The two results were compared by converting Bq/g to µg/g using the specific activity of ^{nat}U. The composition of ^{nat}U is 99.28% ^{238}U, 0.75% ^{235}U and 0.0058% ^{234}U (Eisenbud 1987). The specific activity of ^{nat}U is 1.2 x 10^4Bq/g (Eisenbud 1987). All of the gamma spectroscopy results were less than the detection limit of 0.10 Bq/g. All but the Young's Creek samples also had very low results using ICP-MS analysis, ranging from 0.26 to 1.7 µg/g. These ICP-MS results would correspond to activities of <<0.1 Bq/g; therefore, the two results appear to be comparable. Young's Creek sediments contained 19 µg/g, which converts to 0.23 Bq/g using the specific activity of ^{nat}U. The discrepancy between 0.23 Bq/g and <0.1 Bq/g is small, given laboratory precision when radionuclide activities are close to the detection limit.

The potential for effects on aquatic biota from the observed uranium concentrations cannot be assessed with the chemistry data alone because there are no sediment quality guidelines for uranium and because there are insufficient data to calculate Screening Level Concentrations. The benthic invertebrate community assessment and the monitoring of sentinel fish species (Sections 2.3 and 2.5) provide information on the status of aquatic biota exposed to elevated metal concentrations in water and sediment.

The potential for effects on aquatic biota from the radioactive emissions of uranium can be assessed using the measurement of uranium in activity units (Becquerels or Bq). As noted above, all uranium activities in sediments were less than the detection limit of 0.1 Bq/g. Thus, radioactivity levels in sediments downstream of the Deloro Mine Site were indistinguishable from levels upstream of the Deloro Mine Site and at other reference locations. These radioactivity levels are far below any levels that have been shown to cause effects in aquatic biota (by several orders of magnitude) (IAEA 1992).

The metal concentrations in river sediments collected in shallow water, at water depths of 1 m or less, were in general, less than the metal concentrations reported from sediments collected from deeper water (Table 2.2-4). This trend was most pronounced between the Deloro Mine Site and Moira Lake as is shown below. Metal concentrations below Stoco Lake were lower and the differences between the deep and shallow sediment grab samples were much less distinct.

Table 2.2-4
Comparison of Shallow (<1 m) and Deeper (>1 m) Sediment Metal Concentrations in the Moira River

Parameter (µg/g)	Above Moira Lake		Below Stoco Lake	
	Average Deep	Average Shallow	Average Deep	Average Shallow
Arsenic	1022	496.0	30.0	25.0
Cobalt	895	339.0	73.7	46.5
Lead	43.7	20.4	43.0	47.5
Nickel	556.7	358.6	37.7	30.0

Note: All concentrations in µg/g.

There were also substantial differences in sediment metal concentrations between deeper lake samples and samples taken from near-shore beach areas (Table 2.2-5). The near-shore samples were taken from 1 m and 2 m depths. Differences in metal concentrations are likely attributable to the coarser nature of the substrates in near-shore areas, as well as lower TOC content.

Arsenic concentrations in the Moira River system sediments in 1967 were generally higher than concentrations observed in 1999 (Owen and Galloway 1969). For example, arsenic concentrations upstream of Bend Bay varied from 700 – 870 µg/g in 1967 and were 260 µg/g in 1999 (stations MR-9 and MR-10, Figure 2.2-2). Concentrations in Moira Lake sediments in 1967 varied from 50 µg/g (at the inlet) to 1000 µg/g (west basin). Concentrations in Moira Lake sediments in 1999 varied from 8.8 µg/g to 600 µg/g (Appendix II; Sediment Grab Data). Stoco Lake sediments contained 85 – 220 µg/g in 1967 and 2.1 – 130 µg/g in 1999 (Appendix II; Sediment Grab Data).

Table 2.2-5
Average Metal Concentrations in Near-Shore Area Samples Versus Deeper Samples in Lakes

Chemical	Average Metal Concentration per Location [µg/g]								
	Consecon L. Inlet, Mid-basin, Outlet	Consecon L. Near-Shore	Consecon L. Deep	Moira L. Inlet, Mid-basin, Outlet	Moira L. Near-Shore	Round L. Inlet, Mid-basin, Outlet	Round L. Near-Shore	Stoco L. Inlet, Mid-basin, Outlet	Stoco L. Near-Shore
Arsenic	1.4	0.7	3.8	300.0	79.9	5.2	1.4	84.2	9.8
Cobalt	1.9	0.9	6.3	626.0	132.6	13.7	3.9	112.2	7.7
Copper	5.0	1.8	20.0	119.4	24.1	38.7	8.8	32.8	7.2
Lead	12.7	3.0	49.0	76.0	14.9	77.0	19.0	55.2	8.7
Nickel	3.5	1.4	11.0	454.0	99.1	20.0	5.7	72.6	10.8
Silver	0.0*	0.0*	0.1	8.0	0.7	0.4	0.0*	0.4	0.1
Uranium	0.2	0.4	0.9	1.9	0.7	1.8	0.3	2.3	0.7

* Result based on semi-quantitative method.

The only other study with comparable sediment grab data was in 1996 (Golder 1996). Concentrations at Moira River sites closer to the Deloro Mine Site were similar to these previous data. Samples taken from close to Highway 7 and in Young's Creek in 1996 produced arsenic concentrations ranging from 25-150 µg/g (Highway 7) to 1500 µg/g (Young's Creek) (Golder 1996). These 1996 results are similar to the 1999 data. Analytical methods were the same in the two studies.

2.2.4.2 Sediment Core Samples

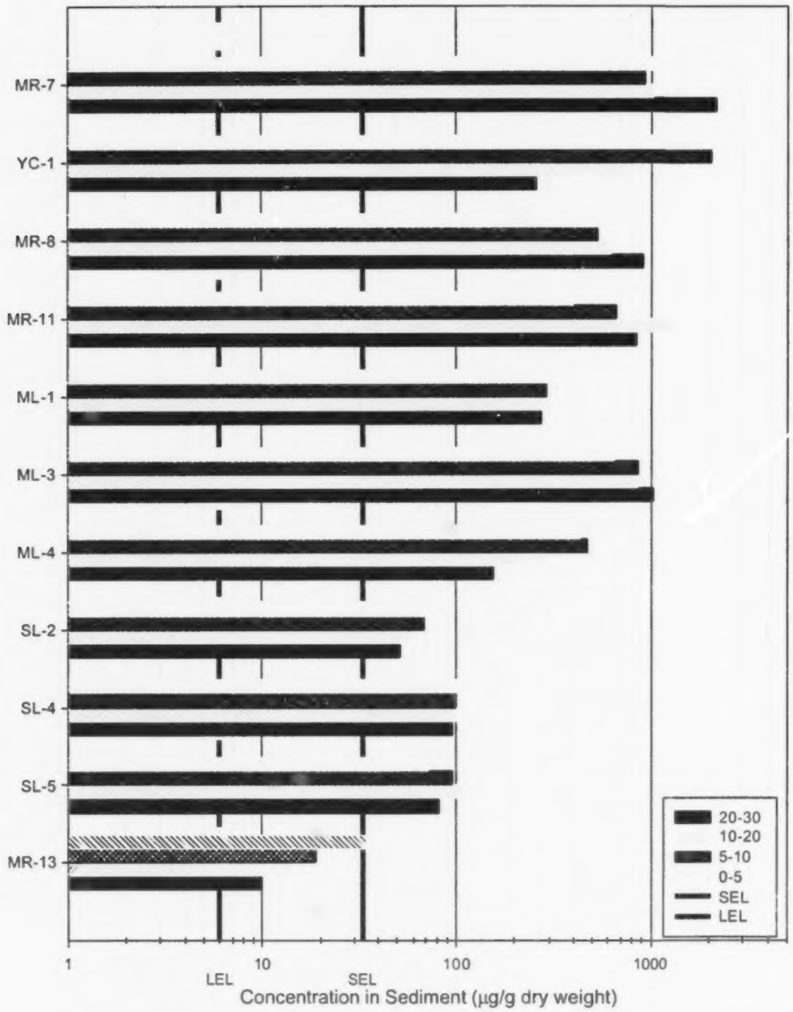
The same overall pattern of metal concentrations with distance downstream of the Deloro Mine Site was evident in the sediment core data (Figures 2.2-9 to 2.2-15). Concentrations were usually highest in Young's Creek (YC-1) and declined substantially after Moira Lake (SL-2, SL-4, SL-5 and MR-13 (Moira River near Roslin).

The sediment profiles from this study show a variation in the relative concentration of metals at the surface (0-5 cm) compared to deeper sediments (Figures 2.2-9 to 2.2-15). At the station in Young's Creek (YC-1), the highest concentrations of arsenic and nickel were found in the upper 5 cm of the profile. This suggests the continuing contribution of these substances from the Deloro Mine Site, at least locally. At some of the lake stations (ML-3, ML-4, SL-5), the concentrations of some metals in the upper 5 cm were lower than in the underlying sediments (presumably reflecting the reduced metal inputs to this section of the Moira system since refining activities at the Deloro Mine Site were discontinued). However, the pattern at these stations was not consistent with metal or with depth of core. Furthermore, in other lake stations (ML-1, SL-2, SL-4) the concentrations in the upper 5 cm were higher than in the underlying sediments. This lack of consistency may reflect the effects of bioturbation (sediment disturbance caused by burrowing invertebrates), diffusion of metals both into the water and deeper into the sediments, and the recent deposition of sediments with lower metal concentrations.

There was a trend to decreasing concentrations with depth below 5 cm for some samples collected from Moira and Stoco lakes as well as from Young's Creek. This was most noticeable for the profiles developed for arsenic and cobalt at YC-1, and arsenic, copper, lead and nickel at ML-1, ML-4 and SL-2 (Figure 2.2-9 to 2.2-13). These results suggest that these areas have been relatively undisturbed. However, for some of the lake sampling stations, (e.g., ML-3 and SL-5), and the river stations, the pattern with depth was inconsistent. For these locations, bioturbation, diffusion, and sediment resuspension and deposition may have disturbed the profile of sediment accumulation.

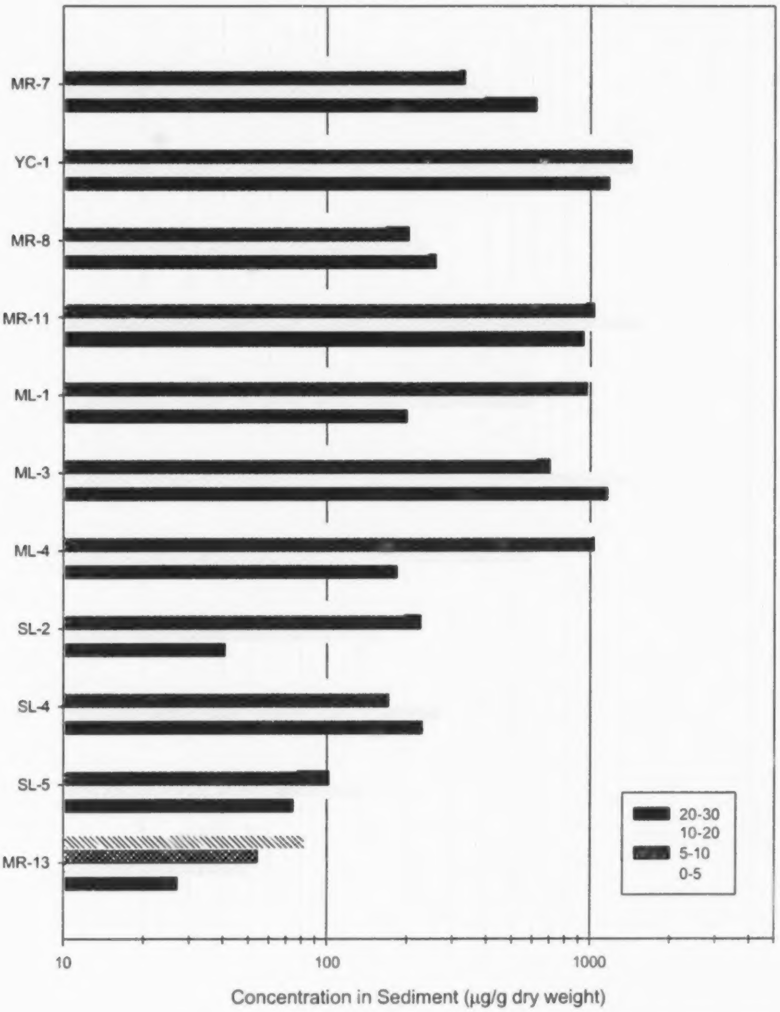
The concentrations of arsenic and nickel exceed the SELs in the lower-most section of most of the core samples (Figure 2.2-9 and 2.2-13). This indicates that materials from the Deloro Mine Site are present to depths below 30 cm, the maximum depth of the sediment cores collected in this study. This contrasts with the results developed by Mudroch and Capobianco (1980) that show elevated metals in sediments were confined to depths of about 25 cm or less in the one core sample collected from Moira Lake.

Figure 2.2-9
Profile of Total Arsenic in Sediment Cores – Moira River Watershed, 1999



Values for 0-5 cm depth represent sum of metals from sequential extraction procedure.

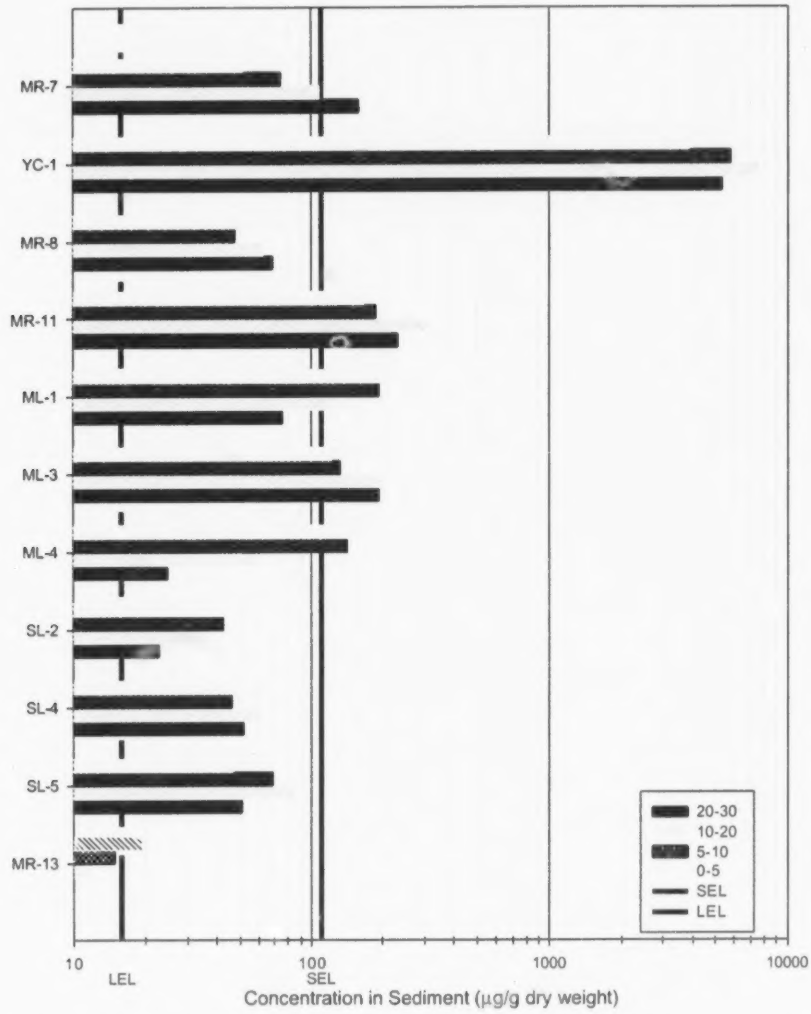
Figure 2.2-10
Profile of Total Cobalt in Sediment Cores – Moira River Watershed, 1999



Plot of total cobalt in sediments, Moira River watershed, 1999

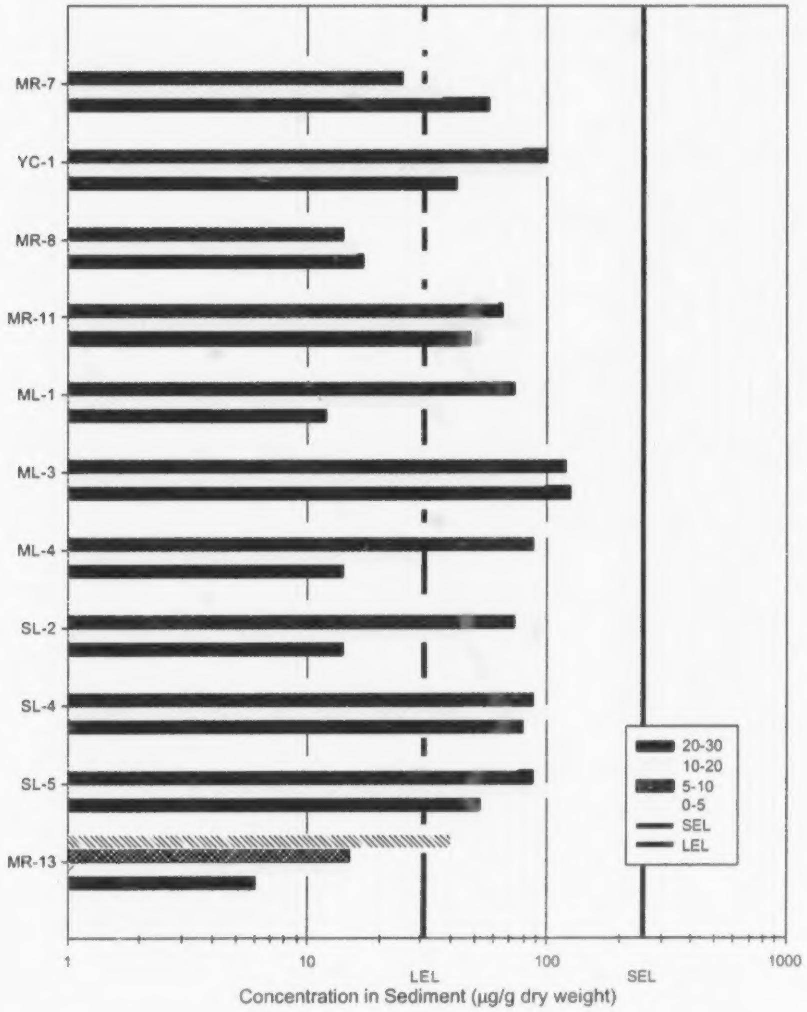
Values for 0-5 cm depth represent sum of results from sequential extraction procedure.

Figure 2.2-11
Profile of Total Copper in Sediment Cores – Moira River Watershed, 1999



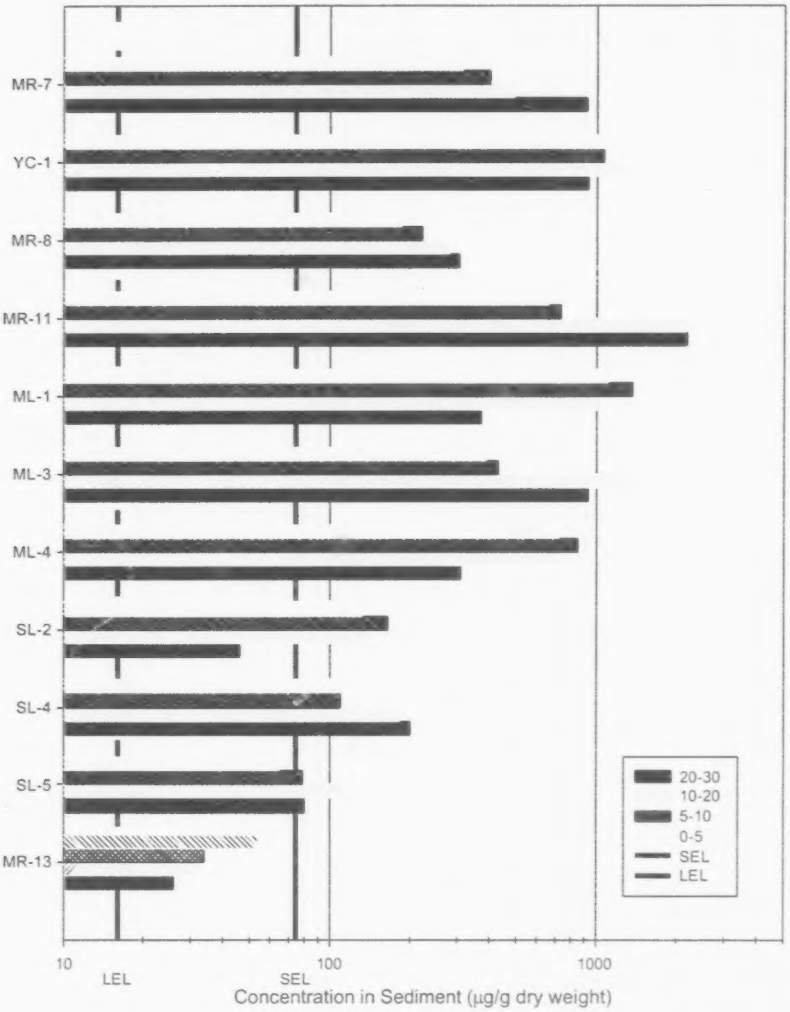
Values for 0-5 cm depth represent sum of results from sequential extraction procedure.

Figure 2.2-12
Profile of Total Lead in Sediment Cores – Moira River Watershed, 1999



Values for 0-5 cm depth represent sum of results from sequential extraction procedure.
Profiles of total lead in sediment cores, Moira River watershed, 1999

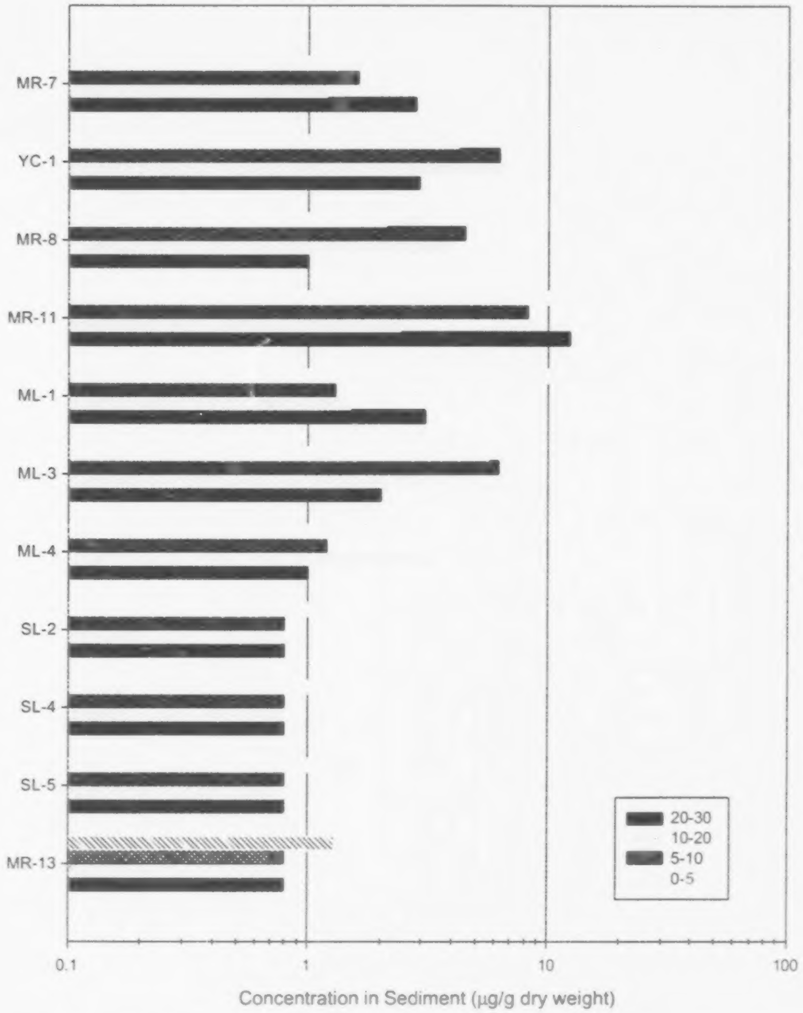
Figure 2.2-13
Profile of Total Nickel in Sediment Cores – Moira River Watershed, 1999



Values for 0-5 cm depth sediment cores; results from sequential extraction procedure.

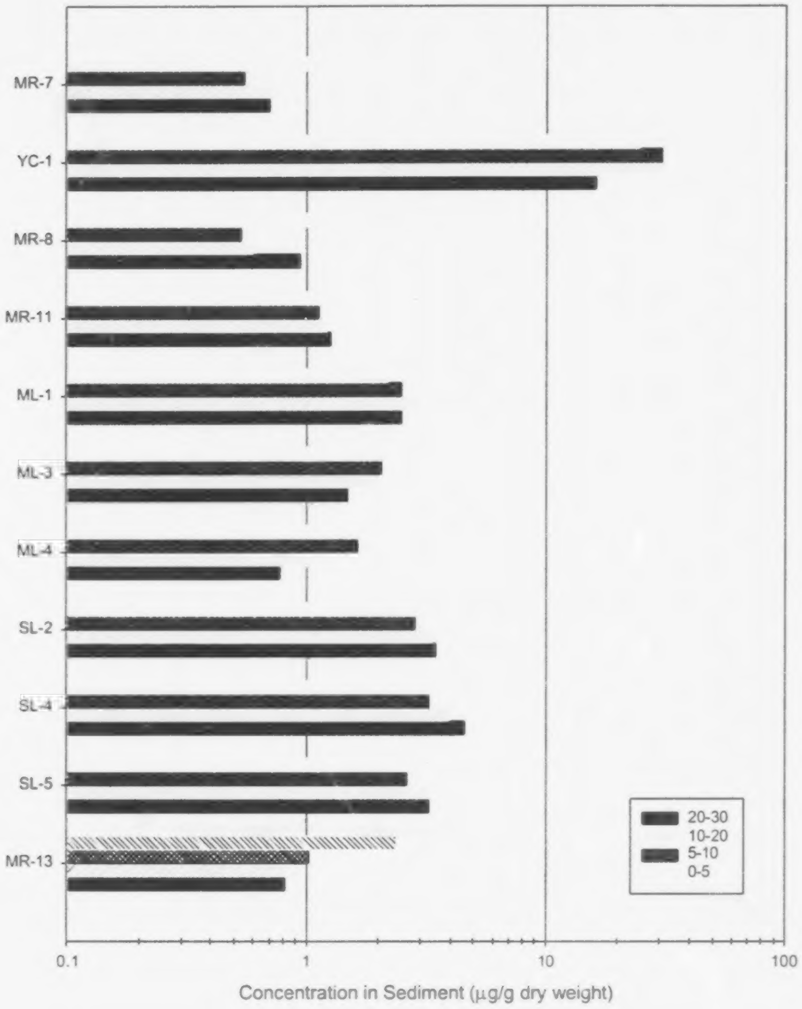
Profiles of total nickel in sediment cores, Moira River watershed, 1999.

Figure 2.2-14
Profile of Total Silver in Sediment Cores – Moira River Watershed, 1999



Values for 0-5 cm depth represent sum of results from sequential extraction procedure.

Figure 2.2-15
Profile of Total Uranium in Sediment Cores – Moira River Watershed, 1999



Values for 0-5 cm depth represent sum of results from sequential extraction procedure.

Mudroch and Capobianco (1980) cored the sediments in the west basin of Moira Lake to a depth of 92 cm and recovered a single core. This core was subsampled into 1 cm sections and analyzed for arsenic, cobalt, nickel and copper concentrations. The profiles developed indicated elevated concentrations of arsenic to a depth of about 25 cm, cobalt and nickel to a depth of about 20 cm and copper to a depth of about 15 cm. Peak concentrations were reported at the 5 cm depth of the profile for all four metals with a marked decrease observed at 0-4 cm for cobalt, nickel and copper. Arsenic concentrations remained relatively constant in the upper 5 cm of the profile reflecting the elevated concentrations of arsenic in the water column. The authors suggested that the lowest depth at which elevated metals concentrations are observed corresponds to the time around 1900 when the Deloro Mining and Smelting Co. began operations. They suggested that the reduction in concentrations observed in the upper 5 cm of the profile corresponds to about 1960 when refining activities ceased.

Other sediment core studies conducted in Moira Lake have reported maximum concentrations from varying sediment depths. Azcue and Nriagu (1993) reported that the highest arsenic concentrations were in the deeper sediment layers (> 20 cm) of Moira Lake. Cornett *et al.* (1987) reported maximum arsenic concentrations at 10 cm and maximum nickel concentrations at 5 cm in Moira Lake. Cornett and Chant (1986) reported maximum arsenic and nickel concentrations in the 10-20 cm sediment layer in Moira Lake.

The range of concentrations found in previous sediment cores from Moira Lake appear similar to those found in this study. For example, the average arsenic concentration in the West and East Basins of Moira Lake was 623 µg/g and 723 µg/g, respectively (Azcue and Nriagu 1993) and Mudroch and Capobianco (1980) reported arsenic concentrations in Moira Lake ranging from 850 to 1237 µg/g. In this study, arsenic ranged from 175 to just over 1000 µg/g in Moira Lake cores. It should be noted that Azcue and Nriagu performed sequential extractions on all sections of the sediment cores. Therefore, the total arsenic concentrations of Azcue and Nriagu cannot be directly compared to the results of this study, except in the 0-5 cm layer. This is because the hydrofluoric/perchloric acid digestion used in the sequential extraction procedure (for the "residual fraction") removes more metal from the sample materials than the nitric acid digestion used for the total metal analysis in this study. Mudroch and Capobianco determined arsenic by X-ray fluorescence, whereas in this study, arsenic was determined by atomic absorption hydride generation. Therefore, a direct comparison between the arsenic concentrations in the two studies is not possible.

In summary, the metal profiles in the sediment cores from this study illustrate a trend to decreasing concentrations with depth at some of the locations sampled for some, but not all, of the metals of concern. The sediment profile may have been disturbed by bioturbation, diffusion and sediment resuspension and deposition processes. The depth of metals originating from the Deloro Mine Site extends below the base of the 30 cm depth cored. The relative concentrations of arsenic in sediment observed in this study appear similar to concentrations reported in earlier studies for the same general locations; however, because different analytical methods were employed in the earlier studies, a direct comparison of the metal concentrations in sediment from the earlier studies cannot be made.

Sequential Extraction Results

Metals are partitioned in sediments in many forms, as soluble free ions, soluble organic (low-molecular-weight humic) and inorganic complexes, easily exchangeable ions, precipitates of metal hydroxides, precipitates with colloidal ferric and manganic oxyhydroxides, insoluble organic complexes, insoluble sulphides, and residual forms (Burton 1992). The residual fraction serves as the matrix vehicle and is associated with labile components (e.g., carbonates, amorphous aluminosilicates, organic matter) that are coated with iron/manganese oxides and organic matter (Burton 1992). This variable coating serves as an active sorption site for metals. Free metals (soluble free ions) are generally thought to possess the greatest toxicity to aquatic organisms; therefore, it is important to understand the relative proportion of metals among various fractions in sediments.

Predicting the partitioning of metals (and, thus, bioavailability) is difficult because of the number and complexity of processes that may simultaneously reduce and increase availability, depending upon the metal. The concentration of metal in porewater of sediments is dependent, to a large degree, on sorption/precipitation processes. The process depends on the metal and the environment. Adsorption is complicated, being related to the solid type, concentration, adsorption species, and surface property changes resulting from interactions such as coagulation (Burton 1992). In addition, sorption-site competition and reaction kinetics of constituents are unknown. High dissolved organic matter concentrations enhance the solubility and complexation of metals. High acid-volatile sulphide concentrations bind cationic metals, reducing bioavailability (Ankley *et al.* 1996, Berry *et al.* 1996). Bioturbation can result in the oxidation of acid-volatile sulphides, thereby releasing some cationic metals back into porewater and increasing bioavailability (Peterson *et al* 1996).

Mobilization of the metals of concern in this study has been associated with several processes, including lowered pH, reducing conditions, changes in the oxidation-reduction conditions of the sediments and the degradation of organic complexes (Burgess and Scott 1992). Given the conditions in the Moira River system, the latter three processes are the most likely to be active. In particular, the deeper depositional areas of the Moira River (such as Bend Bay) and the lake basins are likely to experience seasonal changes in redox conditions. These locations also have greater organic content in the sediment; therefore, these locations contain more organic substrates for metal sorption. However, they would also be more prone to the actions of decomposer organisms, which would degrade organic complexes (such as organo-arsenicals).

Because of the complexity of the processes governing bioavailability, the following results of the sequential extractions should not be interpreted as accurate representations of bioavailability of the metals of concern in the Moira River system. However, they are a reasonable first step in estimating the partitioning of the metals of concern among several important fractions known to be linked to processes that affect bioavailability.

The percent distribution of metals among chemical fractions in the 0-5 cm sediment layer varied with both metal and sample site.

Arsenic was found primarily in the residual fraction at all sites, followed by the iron and manganese oxide fraction (Table 2.2-6). These two fractions accounted for 70 to 88% of the arsenic in the surface sediment layer (0-5 cm). The high proportion in the residual fraction may indicate that most of the arsenic occurs as granular (tailings) material in the Moira River system.

Cobalt was more evenly distributed among the fractions, with approximately equal proportions in the oxide, organic/sulphide and residual fractions in Moira Lake (ML-1, ML-3, ML-4) (Table 2.2-6). For most of the river stations, the carbonate fraction was important, along with the oxide, organic matter and residual fractions. Cobalt at the Young's Creek site (YC-1) was found primarily in the iron and manganese oxide fraction. The variable speciation of cobalt may be due to leaching and runoff processes rather than deposition of mineralized material.

Table 2.2-6
% Distribution of Metals to the Analyzed Components of Sediments

Parameter	Description	ML-1	ML-3	ML-4	MR-11	MR-13	MR-7	MR-8	SL-2	SL-4	SL-5	YC-1
Ag	Exchangeable Metals	1.7%	5.4%	4.6%	1.9%	23.1%	8.1%	14.3%	23.1%	20.0%	21.4%	7.1%
Ag	Metals Bound to Carbonates	1.7%	5.4%	4.6%	1.9%	23.1%	8.1%	14.3%	23.1%	20.0%	21.4%	7.1%
Ag	Metals Bound to Iron and Manganese	1.7%	5.4%	4.6%	1.9%	23.1%	51.4%	19.0%	23.1%	20.0%	28.6%	7.1%
Ag	Metals Bound to Organic Matter	1.7%	5.4%	4.6%	1.9%	23.1%	27.0%	38.1%	23.1%	33.3%	21.4%	7.1%
Ag	Residual Metals	93.3%	78.6%	81.5%	92.4%	7.7%	5.4%	14.3%	7.7%	6.7%	7.1%	71.4%
	Total (0-5cm)	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*
As	Exchangeable Metals	1.9%	6.5%	8.0%	2.9%	9.8%	3.3%	9.1%	8.7%	7.8%	10.7%	1.0%
As	Metals Bound to Carbonates	3.9%	4.4%	2.4%	14.9%	9.8%	7.7%	2.2%	8.7%	7.8%	10.7%	0.4%
As	Metals Bound to Iron and Manganese	22.4%	12.2%	15.7%	19.1%	15.9%	10.1%	4.6%	14.1%	14.6%	18.7%	0.6%
As	Metals Bound to Organic Matter	6.5%	7.4%	7.0%	5.3%	9.8%	11.2%	9.7%	2.2%	4.9%	2.7%	19.2%
As	Residual Metals	65.4%	69.5%	67.0%	57.8%	54.9%	67.7%	74.3%	66.3%	65.0%	57.3%	78.7%
	Total (0-5cm)	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*
Co	Exchangeable Metals	3.7%	2.7%	2.4%	0.4%	1.0%	1.4%	0.8%	0.5%	0.7%	0.2%	1.9%
Co	Metals Bound to Carbonates	10.9%	8.7%	16.3%	5.1%	26.4%	35.3%	25.6%	19.2%	20.7%	11.8%	26.3%
Co	Metals Bound to Iron and Manganese	29.1%	27.5%	42.7%	22.1%	32.1%	14.3%	18.8%	30.7%	26.6%	29.1%	48.1%
Co	Metals Bound to Organic Matter	29.1%	27.5%	24.6%	44.1%	23.6%	15.9%	22.2%	26.3%	26.6%	34.1%	17.7%
Co	Residual Metals	27.2%	33.6%	14.0%	28.2%	16.9%	33.0%	32.6%	23.3%	25.4%	24.7%	6.1%
	Total (0-5cm)	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*
Cu	Exchangeable Metals	1.2%	6.2%	1.4%	1.8%	1.1%	0.7%	1.6%	1.0%	2.4%	2.6%	5.4%
Cu	Metals Bound to Carbonates	8.3%	24.0%	10.6%	10.3%	11.0%	5.3%	8.1%	12.7%	9.3%	9.1%	10.1%
Cu	Metals Bound to Iron and Manganese	36.9%	42.1%	47.2%	44.3%	48.6%	56.2%	34.9%	58.3%	56.1%	51.0%	36.5%
Cu	Metals Bound to Organic Matter	50.7%	24.8%	37.3%	38.1%	19.9%	6.2%	15.5%	16.2%	17.8%	13.6%	40.9%
Cu	Residual Metals	2.9%	2.9%	3.5%	5.5%	19.5%	31.6%	39.9%	11.8%	14.3%	23.6%	7.0%
	Total (0-5cm)	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*
Ni	Exchangeable Metals	32.0%	43.6%	33.0%	45.8%	31.7%	29.5%	35.9%	40.3%	39.4%	46.7%	29.7%
Ni	Metals Bound to Carbonates	10.9%	36.7%	10.3%	26.7%	16.8%	46.7%	38.6%	10.3%	33.7%	26.0%	22.8%
Ni	Metals Bound to Iron and Manganese	57.0%	19.6%	56.6%	27.4%	51.0%	23.5%	25.0%	49.2%	26.6%	26.7%	46.6%
Ni	Metals Bound to Organic Matter	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.1%	0.1%	0.1%	0.3%	0.1%
Ni	Residual Metals	0.1%	0.0%	0.0%	0.1%	0.2%	0.2%	0.5%	0.1%	0.1%	0.3%	0.8%
	Total (0-5cm)	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*
Pb	Exchangeable Metals	34.2%	16.8%	36.3%	15.2%	16.4%	6.7%	10.2%	17.9%	16.3%	10.9%	5.9%
Pb	Metals Bound to Carbonates	3.2%	1.8%	4.5%	3.2%	16.8%	3.9%	11.0%	11.8%	8.3%	7.0%	10.9%
Pb	Metals Bound to Iron and Manganese	30.7%	20.7%	36.8%	21.0%	27.1%	19.6%	21.0%	29.7%	21.8%	27.4%	25.6%
Pb	Metals Bound to Organic Matter	19.9%	30.6%	15.9%	34.7%	21.7%	28.4%	27.6%	24.8%	28.9%	34.5%	34.2%
Pb	Residual Metals	12.1%	30.0%	6.5%	25.9%	18.1%	41.4%	30.2%	15.9%	24.7%	20.2%	23.4%
	Total (0-5cm)	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*
U	Exchangeable Metals	1.3%	4.4%	2.4%	1.1%	3.7%	0.6%	1.1%	1.5%	1.7%	3.1%	3.8%
U	Metals Bound to Carbonates	5.7%	18.6%	9.8%	5.9%	3.7%	2.6%	3.2%	7.5%	5.9%	3.1%	8.6%
U	Metals Bound to Iron and Manganese	28.6%	39.0%	43.1%	36.5%	33.3%	55.3%	31.2%	43.6%	39.0%	33.8%	35.7%
U	Metals Bound to Organic Matter	58.5%	31.0%	39.4%	42.7%	24.1%	6.1%	17.7%	23.3%	26.3%	21.5%	43.7%
U	Residual Metals	5.9%	7.0%	5.3%	13.9%	35.2%	35.5%	46.8%	24.1%	27.1%	38.5%	8.2%
	Total (0-5cm)	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*	*100.0%*

Ag = silver; Ar = arsenic; Co = cobalt; Cu = copper; Ni = nickel; Pb = lead; U = Uranium.

Copper was consistently higher in the oxide fraction (37—58%), followed by the organic matter/ sulphide or residual fraction, depending upon the sampling site (Table 2.2-6). As for cobalt, leaching and runoff processes may be the primary mechanisms for copper input to sediments in the system.

Nickel and lead distribution among the chemical fractions was variable, with no one fraction consistently dominating (Table 2.2-6). Nickel and lead were the only metals with a significant portion in the exchangeable fraction, ranging from 30-47% (nickel) and 6-36% (lead) (Table 2.2-6).

Silver was primarily associated with the oxides and organic matter/sulphide fractions when concentrations were high enough to obtain meaningful distributions (Table 2.2-6). The exception for silver was Young's Creek, where silver was found primarily in the residual fraction. The Young's Creek silver is probably associated with tailings material. The iron and manganese oxides at the river stations likely reflect runoff processes and then exchange with ligands and settling out in depositional areas of the river.

Uranium was associated with the oxides and organic matter/sulphide fractions at all sites, although the residual fraction was also important at some of the river stations (Table 2.2-6). This may reflect a tailings origin, with resuspension at higher flows followed by attachment to ligands and deposition as oxides or with organic matter in depositional areas.

The data suggest that, with the exception of nickel and lead, the metals are primarily in the unavailable residual fraction or in the oxides fraction, where release of metals requires anoxic conditions. Partitioning into the organic matter/sulphides fraction may also be important in limiting the bioavailability of cobalt, copper, silver and uranium in the Moira River system. Therefore, bioaccumulation by benthic invertebrates and subsequent food chain transfer to fish may be limited by the low bioavailability of the metals of concern. In addition, toxicity to benthic invertebrates may also be reduced because of low bioavailability.

The distribution of metals among the chemical fractions is different from the distribution reported in two earlier studies of Moira Lake sediments (Cornett and Chant 1986; Azcue and Nriagu

1993). Comparisons can be made only for arsenic and nickel because the other metals were not measured in previous work.

The main difference in the speciation of arsenic in this study compared to previous studies is the much higher proportion in the residual fraction. Cornett and Chant (1986) reported that 7-10% of the arsenic from Moira Lake core samples was in the residual fraction; the dominant fraction was iron and manganese oxides (62-64%). Similarly, Azcue and Nriagu (1993) found that the oxide fraction was predominant (57%), although they reported a considerably higher percentage (30-37%) in the residual fraction. Both teams interpreted their results as indicating that significant remobilization of arsenic could occur into the overlying water of Moira Lake if sediments at the mud-water interface became anoxic.

The differences in arsenic speciation between earlier studies and this study may be caused by: (1) the fact that only surface sediments (0-5 cm) were analyzed for speciation in this study whereas the entire core sample was analyzed in the earlier studies; (2) differences in particle size or organic carbon content of the sediment samples in the two studies; (3) conversion of oxide-bound arsenic to the residual phases; or, (4) the changing nature of arsenic inputs to the system, causing a different fractional distribution of arsenic in the surface sediment. The first two explanations may be the most important sources of variability between this study and previous work). Characterization of the surface layer only will reflect different physical/chemical conditions and a different time period from an overall average of a 30-cm core. Furthermore, the particle size of the sediments in this study may be coarser than in previous studies (see Appendix II, although equivalent particle size data were not presented for the previous work). Organic carbon was measured using different methods in this study compared to previous studies; however, there do not appear to be major differences in organic carbon content among the three studies (see Appendix II). The core profile presented by Azcue and Nriagu (1993) shows that the oxide and residual fractions have made up over 90% of the arsenic over the time period represented by a 30 cm core, with periodic increases in the oxide fraction. The authors suggested that the core profile indicated that some of the oxide-bound arsenic is being converted to the residual phases. This process may have been continuing, producing the higher proportion of residual arsenic observed in this study. Azcue and Nriagu also comment that the fractional distribution of arsenic in pre-mining sediments would be in the order residual>organic>oxide>exchangeable>carbonate whereas the polluted sediment sequence would be oxide>residual>organic>exchangeable>carbonate. The sequence in this study was residual>oxide>organic>exchangeable>carbonates. This more recent sequence may be indicative of a gradual change related to decreased arsenic loadings from the Deloro Mine Site (as illustrated by the water quality data).

The main difference in nickel speciation between this study and Cornett and Chant (1986) is the much higher proportion of nickel in the exchangeable fraction in this study. Cornett and Chant reported that nickel was found primarily in the oxide and organic fractions (37% and 19-42%, respectively), with a significant proportion in the carbonate fraction (17-35%). In this study, the oxide, exchangeable and carbonate fractions dominated (20-57%, 33-44% and 11-37%, respectively). None of the nickel was found in the organic fraction in this study.

The differences in nickel speciation between Cornett and Chant and this study could be caused by: (1) the fact that only surface sediments (0-5 cm) were analyzed for speciation in this study whereas the entire core sample was analyzed in the earlier studies; (2) differences in particle size or organic carbon content of the sediment samples in the two studies; or (3) changing nature of nickel inputs to the system, causing a different fractional distribution of nickel in the surface sediment. Cornett and Chant found that in the top 4 cm of the cores, < 20% of the nickel was found in the organic fraction. Deeper in the core, the organic fraction contributed 50-70% of the total nickel present. Therefore, the differences in the proportion of nickel found in the organic fraction between this study and Cornett and Chant may be because this study analyzed the 0-5 cm layer only. Examination of particle size data for this study indicates that the sediment samples may be coarser than in Cornett and Chant, although equivalent particle size data were not presented in the earlier study (see Appendix II). Differences in particle size would certainly contribute to significant differences in nickel speciation. Organic carbon was measured using different methods in this study compared to Cornett and Chant; however, there do not appear to be major differences in organic carbon content (see Appendix II). The nature of the nickel entering the Moira system may be changing, because earlier data indicated that nickel inputs were largely in the dissolved form (assumed because sediments in Moira Lake near the Moira River inflow did not have elevated nickel concentrations) (Cornett and Chant 1986). Data from this study show elevated nickel concentrations in sediments in all stations from Highway 7 to Moira Lake. Therefore, the proportion of nickel entering as particulate materials may have increased. This particulate nickel may be re-suspended and re-deposited several times en route to Moira

Lake. Depending upon the nature of the particles and the strength of the adsorptive bond, the particulate nickel may be more or less exchangeable.

The importance of the exchangeable fraction in this study is noteworthy, since this fraction would be the most prone to contributing nickel back into the overlying water of Moira Lake. Furthermore, the porewater concentration of nickel in surficial sediments would be expected to be relatively high. This may contribute to the toxicity of the surface sediments to benthic invertebrates.

References

Ankley, G.T., D.M. DiToro, D.J. Hansen and W.J. Berry. 1996. Technical basis for deriving sediment quality criteria for metals. Environ. Toxicol. Chem. 15(12): 2056-2066.

Azcue, J.M. and J.O. Nriagu. 1993. Arsenic forms in mine-polluted sediments of Moira Lake, Ontario. Environment International 19: 405-415.

Berry, W.J., D.J. Hansen, J.D. Mahony, D.L. Robson, D.M. DiToro, B.P. Shipley, B. Rogers, J.M. Corbin and W.S. Boothamn. 1996. Predicting the toxicity of metal-spiked laboratory sediments using acid-volatile sulfide and interstitial water normalizations. Environ. Toxicol. Chem. 15(12): 2067-2079.

Burgess, R.M. and K.J. Scott. 1992. The significance of in-lace contaminated marine sediments on the water column: processes and effects. Pp 129-165 In: Sediment Toxicity Assessment. G. A. Burton (ed). Lewis Publishers, Boca Raton, FL. 457 pp.

Burton, G.A., Jr. 1992. Sediment collection and processing: factors affecting realism. Pp. 37-66 In: Sediment Toxicity Assessment. G. A. Burton (ed). Lewis Publishers, Boca Raton, FL. 457 pp.

CH2M Gore & Storrie. 1999. Deloro Mine Rehabilitation Project: Extent and Character of Radioactive Materials - Final Report, June, 1999. Submitted to Ontario Ministry of the Environment.

Cornett, R.H., B. Risto and L. Chant. 1986. Kinetics of arsenic and nickel in sediments in Moira Lake. Report to the National Uranium Tailings Program, Canada Centre of Mineral and Energy Technology, Ottawa, Ontario.

Cornett, R.J. and L. Chant. 1986. Speciation of arsenic and nickel in sediments of Moira Lake. Report to the National Uranium Tailings Program, Canada Centre of Mineral and Energy Technology, Ottawa, Ontario.

Eisenbud, M. 1987. Environmental Radioactivity. Third Edition. New York: Academic Press (Harcourt Brace). 473 pp.

Golder Associates Ltd. 1996. Investigation of subsurface and environmental conditions: proposed gas main crossings of Moira River and Young's Creek Highway 7. Prepared for Centra Gas, North York, Ontario.

HåKanson, Lars. 1992. Sediment variability. pp 19-35 In: Sediment Toxicity Assessment. G.A. Burton (ed). Lewis Publishers, Boca Raton, FL. 457 pp.

Jaagumagi, R. Ontario Ministry of Environment and Energy (MOE). Personal communication. March 2000.

IAEA. 1992. Effects of ionizing radiation on plants and animals at levels implied by current radiation protection standards. Technical Report Series No. 332. International Atomic Energy Agency, Vienna.

Mahony, J.D. D.M. DiToro, A.M. Gonzalez, M. Curto, M. Dilg, L.D. DeRosa and L.A. Sparrow. 1996. Partitioning of metals to sediment organic carbon. Environ. Toxicol. Chem. 15(12): 2187-2197.

Mason, S. and J. Dragun. 1996. Natural chemicals in sediments. Amherst Scientific Publishers, Amherst, Massachusetts.

MOE 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ministry of the Ontario Environment (MOE). Pp. 16-18.

Mudroch, A. and J.A. Capobianco. 1980. Impact of past mining activities on aquatic sediments in Moira River basin, Ontario. J. Great Lakes Res. Internat. Assoc. Great Lakes Res. 6(2) 121-128.

Ontario Ministry of the Environment and Energy (MOE). 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Queen's Printer for Ontario.

Peterson, G.S., G.T. Ankley and E.N. Leonard. 1996. Effect of bioturbation on metal-sulfide oxidation in surficial freshwater sediments. Environ. Toxicol. Chem. 15(12): 2147-2155

Powell, M. Ontario Ministry of Environment and Energy (MOE). Personal communication. March 2000.

SCIMUS. 1999. Deloro Mine Rehabilitation Project: extent and character of radioactive materials. Prepared for Ontario Ministry of the Environment by SCIMUS Inc., Toronto, Ontario.

Tessier, A., G.G.C. Campbell and M. Bisson 1979. Sequential extraction procedure for the speciation of particulate trace metals. Analytical Chemistry 51(7): 844-851.

2.3 Benthic Invertebrate Community

2.3.1 Methods

2.3.1.1 Sampling Design

Benthos samples were collected synoptically with bulk sediment chemistry samples and sediments collected for sediment bioassay testing. Because of this, benthic invertebrates were collected from depositional zones only from both lake and river habitats. For the Moira River, sites were typically located immediately upstream of a dam or weir within the low velocity head pond and sediment accumulation zone. Benthic invertebrate abundance data are provided in Appendix II.

Lake Habitat

The benthic invertebrate study for lake habitat focused on benthos communities exposed to elevated metals in Moira Lake, Stoco Lake and the Moira River at Bend Bay, and reference communities in Round Lake and Consecon Lake (Figure 2.2-1). Bend Bay was included in analyses of lake habitat because it exhibits characteristics that are more similar to lentic rather than lotic habitat. For Moira and Stoco lakes, five sites were sampled in each lake corresponding to locations of lake inflow, outflow and deep basins (Figure 2.2-1). Three sites were sampled in Round and Consecon lakes and were similarly located in the vicinity of the inflow, outflow and deep basin of each lake. A single site was sampled at Bend Bay. The general location and UTM coordinates of each sampling site are provided in Table 2.3-1.

River Habitat

Benthos samples were collected at 8 sites in the upper section of the Moira River (upstream of Moira Lake) (Figure 2.2-1). These sites were two upstream reference sites (MR-1, MR-3), and six sites (MR-5 to MR-10) located at increasing distances downstream of the former Deloro Mine Site. An additional site was located in Young's Creek due to concerns regarding high levels of mine-related metal concentrations and issues regarding future mitigative action. Benthos samples were also taken from single reference sites in the Black River and the Skootamatta River. Both rivers are tributaries of the Moira River and provided additional reference data for comparisons with exposed sites.

Table 2.3-1
General Location and UTM Co-ordinates of Benthic Invertebrate Sampling Sites, Lake Habitat, Moira River System, Spring 1999

Lake	Site	General Location	UTMs[a] of Sampling Site
Moira Lake (exposed)	ML-1	west end inflow of lake	301791 E / 4928214 N
	ML-2	western basin of lake	302809 E / 4928013 N
	ML-3	west end of eastern basin	304404 E / 4927371 N
	ML-4	centre of eastern basin	306246 E / 4929806 N
	ML-5	east end at lake outlet	307531 E / 4930164 N
Stoco Lake (exposed)	SL-1	west end inflow of lake	316814 E / 4927085 N
	SL-2	west lake outlet	317526 E / 4925689 N
	SL-3	east lake outlet	318705 E / 4926365 N
	SL-4	centre of south basin	318067 E / 4926536 N
	SL-5	centre of north basin	318427 E / 4928222 N
Bend Bay (exposed)	MR-11	17.5 km D/S[c] of mine, Moira R.	300313 E / 4924406 N
Round Lake (reference)	RL-1	west end inflow of lake	270448 E / 4931270 N
	RL-2	centre deep basin	271168 E / 4930850 N
	RL-3	east end lake outlet	272379 E / 4931229 N
Consecon Lake (reference)	CL-1	west lake outlet	300601 E / 4874344 N
	CL-2	centre basin near north shore	302714 E / 4875869 N
	CL-3	east end inflow of lake	305360 E / 4876154 N
	CL-D[b]	centre basin, deep site	303263 E / 4875436 N

[a] Universal Transverse Mercator (UTM).
[b] Site CL-D was replaced by site CL-2 due to potential anoxic conditions during summer stratification.
[c] D/S = downstream

In the lower Moira River (downstream of Moira and Stoco lakes), benthos samples were taken from four sites, including one located between Moira and Stoco lakes (MR-12) and three located downstream of Stoco Lake (MR-13 to MR-15) (Figure 2.2-1). Suitable reference sites were not available in this section of the Moira River; therefore, reference data were collected from three sites located on the adjacent Salmon River. Sites on the Salmon River were located at approximately the same latitude as the corresponding sites on the Moira River, providing a measure of natural downstream gradients. The general location and UTM coordinates of each sampling site are provided in Table 2.3-2.

Table 2.3-2
General Location and UTM Co-ordinates of Benthic Invertebrate Sampling Sites, River Habitat, Moira River System, Spring 1999

River	Site	Type	General Location	UTMs[(a)] of Sampling Sites
Moira River	MR-1	reference	10.5 km U/S of mine, above Malone	293522 E / 4939459 N
	MR-3	reference	6.5 km U/S of mine, below Malone	293097 E / 4937251 N
	MR-5	exposed	250 m D/S of mine, at Deloro Mine Site	291881 E / 4932012 N
	MR-6	exposed	1.8 km D/S of mine, at Highway #7 bridge	291900 E / 4930664 N
	MR-7	exposed	2.5 km D/S of mine, at old Marmora Road bridge	292387 E / 4930288 N
	MR-8	exposed	4 km D/S of mine, below Young's Creek	293036 E / 4929333 N
	MR-9	exposed	10 km D/S of mine, at Storm Road	295414 E / 4926370 N
	MR-10	exposed	15 km D/S of mine, upstream of Bend Bay	298004 E / 4925172 N
	MR-12	exposed	Between Moira/Stoco lakes, below Skootamatta R.	314356 E / 4931516 N
	MR-13	exposed	Below Stoco Lake, near Roslin	316222 E / 4913680 N
	MR-14	exposed	Below Stoco Lake, near Latta	313558 E / 4908192 N
	MR-15	exposed	Below Stoco Lake, between Plainfield and Foxboro	310870 E / 4904931 N
Young's Creek	YC-1	exposed	Beaver pond upstream of confluence	293037 E / 4929741 N
Black River	BR-1	reference	Downstream of Highway #7	311642 E / 4934280 N
Skootamatta River	SKR-1	reference	Upstream of Highway #7	315035 E / 4935606 N
Salmon River	SR-1	reference	At Roslin	339091 E / 4915551 N
	SR-2	reference	At Forest Mills	337375 E / 4911391 N
	SR-3	reference	At Lonsdale	330459 E / 4904602 N

U/S = upstream; D/S = downstream.

2.3.1.2 Sample Collection

The Ontario Ministry of the Environment (MOE) conducted field sampling from April 22 to May 12, 1999. Exact sampling locations (i.e., deposition zones) were finalized in the field to ensure that all sites were similar in habitat characteristics. Three replicate samples were taken at each lake and river site. Benthos samples were collected using a Ponar grab (0.05 m^2) for lakes and deep river sites. An Ekman grab (0.05 m^2) was used at all river sites that could be easily waded. Sampling dates for each site, as well as the range in grab fullness, are presented in Table 2.3-3. Each sample was sieved in the field using a #30 Tyler sieve (600-μm mesh) and preserved immediately in 10% buffered formalin. Benthic samples were shipped to Mr. William Morton, Guelph, Ontario for sorting and taxonomic identification. Chain-of-custody forms were used to document shipping procedures and to ensure sample integrity.

Table 2.3-3
Sampling Date and Grab Fullness for Each Lake and River Benthos Site, Moira River System, Spring 1999

Habitat	Waterbody	Site	Date Sampled	% Fullness of Grab[a]
Lake	Moira Lake	ML-1	22-Apr-99	100
		ML-2	22-Apr-99	100
		ML-3	26-Apr-99	100
		ML-4	27-Apr-99	100
		ML-5	27-Apr-99	90
	Stoco Lake	SL-1	22-Apr-99	100
		SL-2	22-Apr-99	100
		SL-3	22-Apr-99	30-50
		SL-4	22-Apr-99	100
		SL-5	22-Apr-99	100
	Bend Bay, Moira R.	MR-11	27-Apr-99	100
	Round Lake	RL-1	23-Apr-99	100
		RL-2	23-Apr-99	100
		RL-3	23-Apr-99	100
	Consecon Lake	CL-1	26-Apr-99	80
		CL-2	26-Apr-99	100
		CL-3	26-Apr-99	25
		CL-D	3-May-99	80
River	Moira River	MR-1	30-Apr-99	10
		MR-3	12-May-99	10
		MR-5	28-Apr-99	25-30
		MR-6	30-Apr-99	30
		MR-7	28-Apr-99	10-20
		MR-8	28-Apr-99	10-20
		MR-9	30-Apr-99	N/A
		MR-10	27-Apr-99	100
		MR-12	29-Apr-99	80
		MR-13	29-Apr-99	30-50
		MR-14	29-Apr-99	30-50
		MR-15	29-Apr-99	30-40
	Young's Creek	YC-1	28-Apr-99	80
	Black River	BR-1	3-May-99	N/A
	Skootamatta River	SKR-1	3-May-99	N/A
	Salmon River	SR-1	3-May-99	10-20
		SR-2	3-May-99	10
		SR-3	3-May-99	N/A

[a] range from three replicates/site.
N/A - not available.

Supporting environmental data measured at each site included water depth, temperature and conductivity. Sediment grain size data and total organic content were also available from results of bulk sediment analyses (Appendix II). This information was used to evaluate similarity among sites and identify potential influences on benthos community structure other than mine-related metal contamination.

2.3.1.3 Sample Sorting and Taxonomic Identification

Benthos samples were initially treated with rose bengal stain for at least 24 h to facilitate sorting. Samples were then washed with water using a 425-µm sieve (US #40) to remove preservative and excess stain. Sorting was performed by placing the sample in a gridded pan and viewing it under a dissecting microscope (10x magnification). Entire samples were sorted when possible; however, sub-sampling was required for samples that were large in volume (typical of grab samples from depositional areas) (Table 2.3-4). When sub-sampling was required, the sample was evenly distributed in a 425-µm sieve and divided in half. Half of the sample was removed and archived, while the remaining half was either processed or sub-sampled further. Sorting typically started with a 1/8 or 1/4 sub-sample. Sorting efficiency was estimated by randomly selecting 10 samples (9.2%) and re-sorting the originally sorted material. Any specimens found in the re-sorting procedure were compared against the original data. Sorting efficiency of ≥90% was considered acceptable.

Invertebrates were identified to the lowest practical level (species when possible) and enumerated. A reference collection containing specimens of each taxon was maintained and identifications verified by recognized experts including:

- Annelida: Dr. David Barton, University of Waterloo, ON
  Kathryn Coates, Royal Ontario Museum, Toronto, ON
- Acarina: Dr. Ian Smith, Agric. Canada, Biosystatics Research Farm, Ottawa, ON
- Amphipoda: Dr. Ed Bousefield, National Museum, Ottawa, ON
- Isopoda: Famina Rafi, National Museum, Ottawa, ON
- Decapoda: Dr. Dave Barr, Royal Ontario Museum, Toronto, ON
- Chironomidae: Dr. Len Ferrington, Lawrence, KA
  Dr. Don Oliver, Agric. Canada, Biosystematics Research Farm, Ottawa, ON
- Ephemeroptera: Dr. Bob Waltz, Indiana Dept. Natural Resources, Indianapolis, IN
- Trichoptera: Dr. John Morse, Clemson University, Clemson, SC
  Pat Schaefter, Royal Ontario Museum, Toronto, ON
- Mollusca: Dr. Gerry Mackie, University of Guelph, Guelph, ON

Table 2.3-4
Percent of Benthos Sample Sorted for Taxonomic Identification, Moira River System, Spring 1999

Habitat	Waterbody	Site	% of Sampled Sorted		
			Rep. 1	Rep. 2	Rep. 3
Lake	Moira Lake	ML-1	25	50	25
		ML-2	50	50	50
		ML-3	12.5	12.5	12.5
		ML-4	12.5	12.5	12.5
		ML-5	12.5	12.5	12.5
	Stoco Lake	SL-1	12.5	12.5	12.5
		SL-2	100	100	100
		SL-3	50	50	50
		SL-4	100	100	100
		SL-5	100	100	100
	Round Lake	RL-1	25	12.5	25
		RL-2	100	100	100
		RL-3	50	100	100
	Consecon Lake	CL-1	25	25	25
		CL-2	50	50	25
		CL-3	50	50	50
		CL-D	25	25	25
River	Moira River	MR-1	25	25	25
		MR-3	12.5	12.5	12.5
		MR-5	12.5	25	25
		MR-6	12.5	25	12.5
		MR-7	12.5	50	25
		MR-8	25	12.5	25
		MR-9	12.5	6.25	6.25
		MR-10	6.25	6.25	6.25
		MR-112	5	25	12.5
		MR-12	6.25	6.25	6.25
		MR-13	12.5	12.5	6.25
		MR-142	5	25	25
		MR-15	12.5	12.5	12.5
	Young's Creek	YC-1	12.5	12.5	12.5
	Black River	BR-1	12.5	12.5	12.5
	Skootamatta River	SKR-1	12.5	12.5	12.5
	Salmon River	SR-1	12.5	25	25
		SR-2	25	25	25
		SR-3	12.5	12.5	12.5

N/A - not available.

2.3.1.4 Sediment Toxicity Tests

Sediment grab samples collected at the benthic invertebrate sampling sites were tested for toxicity using a battery of three tests, including:

- *Hyalella azteca* (14-day) survival and growth (Protocol EPS 1/RM/33; Environment Canada 1997a);
- *Chironomus riparius* (10-day) survival and growth (Protocol EPS 1/RM/32; Environment Canada 1997b); and
- Fathead Minnow (*Pimephales promelas*) juvenile (21-day) survival and growth (Ontario Ministry of the Environment Laboratory Sediment Biological Testing Protocol; Bedard *et al.* 1995).

Toxicity tests were carried out by ESG International, Guelph, Ontario (*Hyalella* and *Chironomus*) and HydroQual Laboratories, Calgary, Alberta (Fathead minnow).

All of these tests were conducted within six weeks of sample collection. However, the *Chironomus riparius* test had to be re-run because of problems with the performance of the controls. The second run of the *Chironomus riparius* test was conducted 7 weeks after the sediments were collected.

2.3.1.5 Data Analysis

Data Preparation

The raw abundance data were checked for data entry errors by the taxonomist and corrections were made as necessary. To prepare the data for analysis, non-benthic and terrestrial taxa were deleted and the abundance of taxa per sample were converted to abundance per square metre.

General Approach

The alternatives for analysis of the benthos data included the gradient approach (e.g., regression analysis using sediment metal concentrations as the independent variable), or comparisons of means of site groups representing discrete levels of sediment metal concentrations (e.g., ANOVA). Since there was no recent information on sediment chemistry at the study design phase, the exact approach could not be identified prior to availability of the spring 1999 field data. To select the analytical approach, the spatial variation in sediment metal concentration was first examined for each habitat type (river and lake). The approach was then selected according to the following principles: if there were distinct groups of sites representing similar levels of metals in sediments (e.g., background, low, moderate, high), then comparison of these groups as "treatments" would be appropriate using ANOVA or ANCOVA. Alternatively, if the sites sampled represented a wide range of sediment metal concentrations without obvious grouping, then a gradient-type analysis, such as linear regression would be applicable.

Raw metal concentrations were used to select the appropriate statistical approach. The metals included in the analysis were those identified as metals of concern after screening for differences with reference concentrations and exceedances of Provincial Water Quality Objectives (Section 2.1). The sediment data were not normalized because at the present there is no general consensus regarding the best procedure to normalize sediment metal data. Additionally, initial examination of the sediment data did not suggest any obvious choices for normalization. There were no significant correlations between levels of any of six metals of concern (arsenic, cobalt copper, lead, nickel, silver) at lake sites with sediment particle size (% sand, silt, clay), but copper, lead and silver were correlated with sediment total organic carbon (TOC). At river sites, copper was correlated with % silt, and lead was correlated with all sediment variables, but no other correlations were found. Uranium was not included in these analyses because it was significantly elevated only in the Young's Creek sample.

Sediment metal concentrations were generally similar within each lake, but varied among lakes (Figure 2.3-1 and Section 2.2). Sediments in the two reference lakes were characterized by low concentrations of all metals, though Round Lake sediments had higher concentrations compared to Consecon Lake. In particular, lead concentration was higher at two Round Lake sites than at the other four reference sites. Stoco Lake sediments had low levels of metals, and moderate to high levels were found in Moira Lake sediments. The sediment sample collected at the single site in Bend Bay had particularly elevated concentrations of four of the six metals of concern. Based on this information, the ANOVA/ANCOVA approach was adopted for analysis of the lake data set, using each lake as a treatment and the sampling site as the unit of replication.

In the river data set, there was no clear grouping of exposed river sites with respect to sediment metals (Figure 2.3-2 and Section 2.2). Below the former Deloro Mine Site, a gradual increasing trend was found in arsenic, cobalt, copper, nickel and lead from sites MR-5 to MR-7, followed by high but variable levels of each metal from MR-8 to MR-10. Silver concentrations were

Figure 2.3-1
Metal Concentrations in Sediment at Benthic Invertebrate Sampling Sites in Lake Habitat, Moira River System, Spring 1999

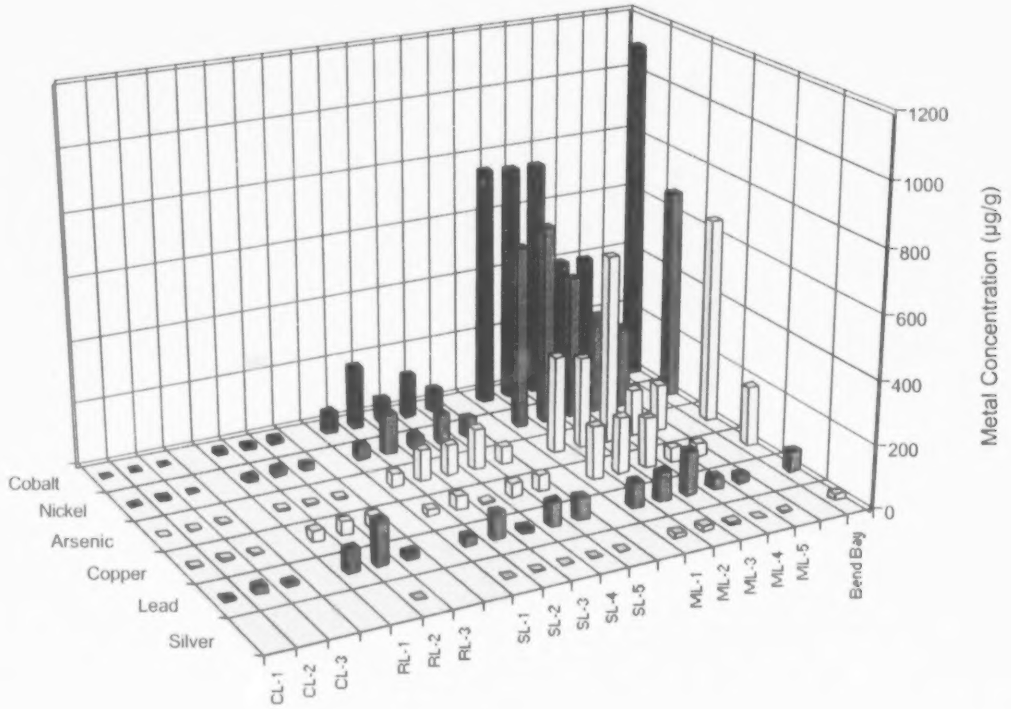
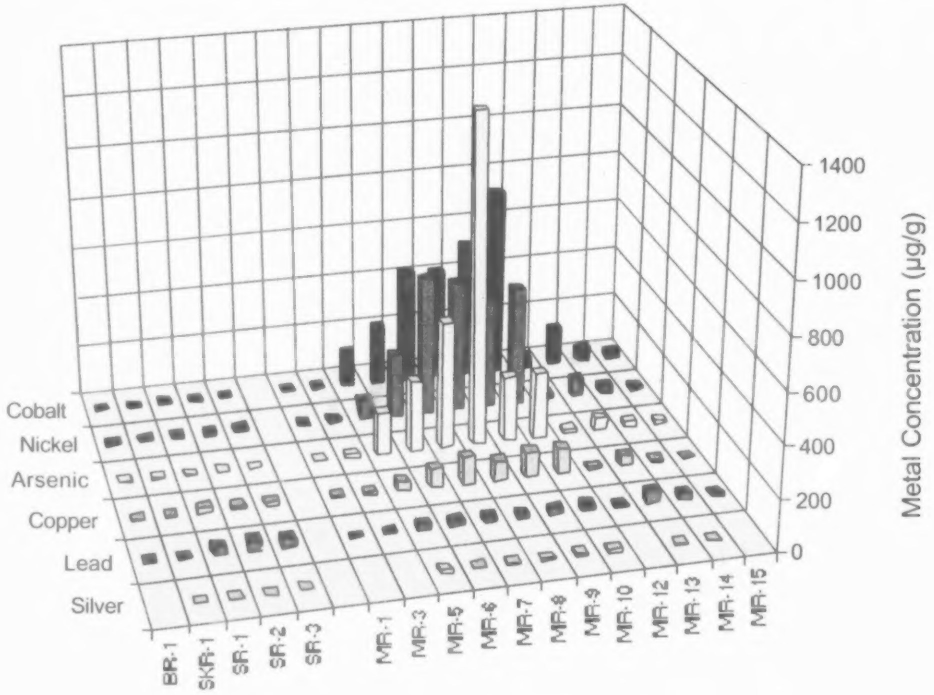


Figure 2.3-2
Metal Concentrations in Sediment at Benthic Invertebrate Sampling Sites in River Habitat, Moira River System, Spring 1999



much lower than those of the other metals, but exhibited a similar spatial trend. In the lower Moira River, concentrations of most metals of concern were close to background, with the exception of site MR-13 (first site below Stoco Lake), where concentrations were similar to those at MR-5. Based on the large variation in metal concentrations among sites and the lack of site groups with similar levels of sediment metal concentrations, the gradient approach using linear regression was adopted for the analysis of the river benthic invertebrate data set.

Lake Habitat

Benthic community variables were compared among lakes using one-way ANOVA or ANCOVA, followed by Tukey's tests comparing the two reference lakes (Consecon and Round) and each exposed lake (Moira and Stoco) with each reference lake. Because only a single site was sampled in Bend Bay, it was excluded from the statistical tests, but was shown on graphs for each biological variable tested and was included in the Sediment Quality Triad (SQT) analysis (see below). Site CL-D (17.25-m deep site in Consecon Lake) was excluded from the lake data analysis because it was considerably deeper than all other sites (4 to 10 m) and would have been influenced by persistent anoxic conditions during summer stratification (Section 2.1).

A relatively large number of benthos variables were included in these comparisons, because there is considerable variation in the specific variables that have proven useful in studies of metal concentrations (Clements 1991). Community-level variables included total abundance, taxonomic richness, abundance of major taxonomic groups and the percentage of total abundance represented by those groups. Additionally, individual taxa (at the lowest level of identification) were selected for the analysis based on initial graphical examination of the data. Common taxa (i.e., those accounting for ≥1% of the total number of invertebrates in the lake data set) that appeared to vary in abundance in response to metal concentrations were included in the statistical analysis.

A number of additional biological variables were also included in the statistical analysis to allow assessment of trends in the abundance and percentage of metal-sensitive and metal-tolerant invertebrates. Abundances of metal-sensitive and metal-tolerant organisms were summed and were also expressed as the percentage of total abundance for statistical tests. Species-specific information on metal sensitivity (Klemm *et al.* 1990) and more general information on sensitivity of higher taxonomic groups (Mance 1987, Clements 1991) were used to derive these variables.

Because very few of the taxa in the study area were designated as metal-tolerant or sensitive by Klemm *et al.* (1990), it was necessary to rely on the more general information regarding metal-sensitivity. Metal-tolerant invertebrates included *Limnodrilus* spp., *Tubifex tubifex*, and midges in the subfamilies Orthocladiinae and Tanypodinae. Tanypodinae midges were included in this group because they have been shown to comprise a larger fraction of the community at sites affected by mine-related metals (Winner *et al.* 1980, Clements 1991). Sensitive invertebrates included all mayflies (Ephemeroptera), and midges in the tribes Tanytarsini and Chironomini. Although not all Chironomini midges are metal-sensitive, Clements (1991) showed their general sensitivity to one metal (copper) in outdoor stream mesocosms. Additionally, more than half of the Chironomini genera in the present data set were either metal-sensitive, or had at least one sensitive species according to sensitivity designations by Klemm *et al.* (1990).

The sensitivities of benthic taxa to arsenic and metals were compared based on studies of rivers that contained arsenic in addition to heavy metals (Canfield *et al.* 1994, Poulton *et al.* 1995, Beltman *et al.* 1999, Mori *et al.* 1999). These studies reported similar impacts on benthos between sites containing arsenic and sites containing arsenic plus metals, and identified the same taxonomic groups as sensitive or tolerant. Therefore, in the absence of specific information on arsenic-sensitivity of benthic taxa, it was assumed that metal-sensitive taxa were also sensitive to arsenic, and to about the same degree.

Since there was a strong mean-variance relationship for all abundance variables, the abundance data were log(x+1) transformed before statistical analysis. Percentage-type variables were arcsin-transformed. Richness variables were not transformed, as no violations of the assumptions of parametric tests were found.

The relationships between benthic community variables and physical variables were investigated to identify potentially confounding factors and to select covariates for statistical tests. First, the range in each physical variable was examined to evaluate whether the range was wide enough to influence invertebrate communities, or to act as a confounding factor. This examination eliminated water temperature, conductivity and sediment particle size. Then, Pearson correlation coefficients were generated between each biological variable (transformed as above) and the remaining physical variables (depth, TOC). Significant correlations were examined as scatter-plots to determine whether they represented real trends (i.e., not resulting from one or a few atypical points). The physical variables that were correlated with biological variables were then used as covariates in the ANCOVA analyses.

River Habitat

The relationships between benthic invertebrate variables and metal concentrations in bottom sediments were evaluated using linear regression analysis. The dependent variables (i.e., biological variables) included those described above for the lake data analysis. Abundance variables were log(x+1) transformed before analysis. The independent variables included concentrations of the metals of concern (summarized as a single variable [PC1] by Principal Component Analysis [PCA], described below), water depth, % fine sediments (% silt + %clay) and sediment TOC. The single site sampled in Young's Creek was excluded from the analysis because of habitat differences (it is a very small stream compared with the other watercourses sampled) and because the high sediment metal concentrations at this site would act as outliers during data analysis or result in high leverage in regressions.

To reduce the number of independent variables to a minimum, a Pearson correlation matrix was generated to assess correlations between each biological variable and the three major habitat variables (water depth, % fine sediments, TOC). The habitat variables that were significantly correlated with the biological variables, if any, were then used in combination with sediment chemistry in multiple regressions against the biological variables. In the event that none of the habitat variables were correlated with a biological variable, sediment chemistry PC1 was used as the only independent variable. To ensure that the best set of independent variables was found (i.e., the combination that explains the maximum amount of the variation in the dependent variable), regressions were run using each independent variable by itself and in all possible combinations with the other independent variables and sediment chemistry PC1.

In addition to the above analysis, the three sites sampled in the lower Moira River (MR-13, MR-14, MR-15) were compared with the corresponding reference sites in the Salmon River (SR-1, SR-2, SR-3), as planned during the study design phase. Because the supporting data indicated that there was a strong declining trend in TOC with distance downstream in both rivers, the biological variables were compared between rivers using paired t-tests, which allowed matching of sites with regard to sediment TOC content.

Multivariate Analysis

The lake and river benthic data sets were summarized separately by ordination to assess the variation in community structure among sites and to generate community summaries for the Sediment Quality Triad (SQT) analysis. Non-metric Multidimensional Scaling (NMDS) was used for this analysis. NMDS is a non-parametric ordination method that allows reduction of a data set consisting of a large number of variables (taxa in this case) to typically two or three new dimensions (analogous to ordination axes) (Clarke 1993). NMDS is considered more useful than PCA to summarize biological data because: it does not assume linear responses along environmental gradients; it is less sensitive to outliers; it is appropriate for data encompassing long environmental gradients; and, it is not limited by the number of variables that can be included in the analysis (although some degree of data reduction is still recommended before running NMDS) (Paine 1998).

Before performing the ordinations, the lake and river data sets were reduced to exclude rare taxa, defined as those that collectively constituted <2% of the mean total number of invertebrates in each data set. This procedure reduced the number of taxa from 68 to 39 in the lake data set and from 117 to 65 in the river data set, while retaining 98% of the original number of invertebrates in each data set. The reduced abundance data were log(x+1) transformed before ordination to reduce the influence of dominant taxa on the ordination results. A Bray-Curtis distance matrix was generated from the transformed abundance data (as recommended by Clarke 1993) and was used as the input for the ordination. Two dimensions were selected for the ordination to facilitate the interpretation of results, after confirming that the stress of the two-dimensional configuration was reasonably low (<0.2) for both the lake and river data sets.

Ordination results were presented as two-dimensional scatter-plots of the sampling sites in ordination space. To facilitate recognition of trends in community structure with sediment metal concentrations, the sizes of symbols representing sites were scaled to reflect the relative degree of sediment arsenic concentration at each site. Correlations between ordination scores, physical variables and sediment chemistry were assessed using Spearman rank correlation analysis. Since NMDS does not provide an indication of the taxa associated with each dimension (only inter-site distances are used in the analysis), Spearman rank correlation coefficients were also generated between each dimension and abundances of the taxa in the reduced biological data set used for the ordination.

Sediment Quality Triad

The present study collected information describing benthic community structure, sediment chemistry and sediment toxicity. These components make up the basis of what has been referred to as the Sediment Quality Triad approach (SQT) proposed by Long and Chapman (1985), Chapman *et al.* (1987) and Chapman (1990). Chapman *et al.* (1991) argued that the SQT incorporates three essential components: 1) measures to determine the presence and degree of anthropogenic metal concentrations (i.e., bulk sediment chemistry); 2) measures that demonstrate that substances are present that can interfere with the normal functioning of at least some biological organisms tested in the laboratory (i.e., sediment toxicity tests); and, 3) measures of *in situ* alteration of resident biological communities (i.e., benthic community structure).

Although each component provides important information regarding the magnitude and spatial extent of potential environmental effects, the SQT attempts to integrate information from each component by examining the relationships or associations among biological, chemical and toxicological data. In essence, concordance among data sets provides the weight of evidence that observed biological effects are related to metals in the system (i.e., infers possible causation).

To relate the three data sets (benthos, sediment chemistry and toxicity) accumulated during the spring 1999 field survey, a variant of the two-step methods described by Green *et al.* (1993) was used. This method consists of first summarizing the pattern within each data set using ordination and then relating the within set patterns (ordination axes) to each other using correlation analysis. This approach allows description of within-set patterns based on the ordinations, which can provide important information for the interpretation of triad results. Separate SQT analyses were carried out for each habitat type (river and lake).

The biological data set was summarized using NMDS, as described above. This analysis generated two dimensions (ordination axes) which were both included in the SQT analysis. Total invertebrate abundance and taxonomic richness were also included as additional biological variables in the SQT because relationships between these basic community variables and sediment chemistry/toxicity are usually considered ecologically meaningful and are useful in evaluating the severity of biological effects. Benthos data and associated sediment chemistry data were available for 17 sites in each habitat type, excluding Site YC-1 from the river data and Site CL-D from the lake data for reasons discussed above.

Sediment chemistry and toxicity data sets were each summarized using Principal Component Analysis. The raw chemistry data were used for the chemistry PCA, including concentrations of five of the six metals of concern in sediment grab samples collected at the benthic invertebrate sites (arsenic, cobalt, copper, lead, nickel). The data for silver were not used because they were incomplete (i.e., no data for four sites). Exclusion of this metal from the analysis was unlikely to affect ordination results because silver concentrations were positively correlated with those of most other metals of concern.

Before ordination of the toxicity data, each test result was expressed as the % of the control test result (% control). This was necessary to standardize the data across sites, because two batches of tests were run, each with its own control sediment. In addition, the number of toxicity variables was reduced by omitting results for fathead minnow survival and weight. The fathead minnow data were invalid due to problems with dissolved oxygen concentrations during the test (Appendix III, Table 8). Therefore, the variables used in the toxicity PCA included *Hyalella azteca* survival and weight and *Chironomus riparius* survival and weight. The detailed toxicity test results are presented in Appendix III. Toxicity data were only available for 13 sites in each habitat type.

A Spearman rank correlation matrix was generated to evaluate the relationships among the three SQT components.

2.3.2 Results and Discussion

2.3.2.1 Lake Habitat

Variation in Habitat

Field measurements revealed differences among lakes in conductivity (Table 2.3-5), which largely reflected the transition from shield to limestone bedrock in the study area (generally from north to south, or in a downstream direction) and the source of water inflows to each lake. The two reference lakes were at the two extremes in conductivity. Round Lake is located on the Canadian Shield, where surface waters typically have low levels of dissolved ions. Consecon Lake is located on limestone bedrock, which usually results in elevated dissolved ion levels relative to shield lakes. In the Moira River system, the decline in conductivity from Bend Bay and Moira Lake to Stoco Lake reflected the inputs of water from the Black and Skootamatta rivers, which drain shield areas and account for the majority of the inflow to Stoco Lake (Owen and Galloway 1969). Overall, although conductivity varied among lakes, the variation observed was within the typical range for surface waters in central Ontario and was unlikely to appreciably influence benthic community structure.

Table 2.3-5
Variation in Field Water Quality Parameters, Depth and Sediment Particle Size Among Lake Sites, Moira River System, Spring 1999

Site	Water Depth (m)	Conductivity (µS/cm)	Water Temp. (°C)	Sediment Characteristics			
				Clay (wt. %)	Silt (wt. %)	Sand (wt. %)	TOC (wt. %)
Consecon Lake							
CL-1	4.5	345	8.3	22	62	16	2.4
CL-2	10.0	345	8.3	23	66	11	6.6
CL-3	6.0	343	8.9	13	43	44	2.1
CL-D	17.3	362	13.6	25	69	6	7.2
Round Lake							
RL-1	4.8	184	9.1	6	64	30	27
RL-2	9.0	189	9.2	6	67	27	22
RL-3	7.0	185	8.5	7	77	16	21
Stoco Lake							
SL-1	3.8	170	10.1	9	55	34	8.1
SL-2	5.4	172	9.3	15	74	11	9.9
SL-3	4.0	171	8.8	8	25	67	0.8
SL-4	9.7	171	9.6	15	73	12	10
SL-5	7.0	200	11.6	13	68	19	7.6
Moira Lake							
ML-1	5.2	250	11.8	8	69	23	20
ML-2	8.0	250	11.1	7	67	26	20
ML-3	9.7	280	10.3	8	66	26	17
ML-4	6.9	263	9.3	6	52	42	6.3
ML-5	4.0	264	9.3	8	55	37	6.6
Bend Bay							
MR-11	4.0	261	12.3	10	67	23	14

Oxygen depletion occurred at the sediment-water interface in Consecon, Stoco and Moira lakes (based on single profiles in each lake). This created concern regarding the suitability of Round Lake as a reference lake because Round Lake did not show oxygen depletion. Although the potential for anoxia was considered during the selection of reference sites (e.g., one deep Consecon Lake site was excluded from the data analysis), the available dissolved oxygen profile data were too limited to justify excluding Round Lake from the analysis.

Other physical variables also varied among sites and lakes. Temperature measured at the water surface was similar at most lake sites (Table 2.3-5). Vertical variation in temperature was small at the time of sampling except in Consecon Lake in mid-summer, where a thermocline was present between 9 and 11 metres (Section 2.1). Water depth varied substantially among sites, even without the deep site in Consecon Lake (CD-D; excluded from the data analysis) (Table 2.3-5). Bottom sediments consisted mostly of silt and clay at the majority of sites, with relatively little variation. The only exception was Site SL-3 in Stoco Lake, where the sediments were dominated by sand. Sediment TOC content varied widely among sites, sometimes reflecting particle size distribution (i.e., TOC was low at the sandy site), but also exhibiting noticeable among-lake differences. In particular, Round Lake sediments had high organic carbon content, and the greatest within-lake variability in TOC was found in Moira Lake.

The variation in the physical attributes of sampling sites was sufficient to account for part of the variation in benthic community structure in the study area. Thus, physical variation could have obscured biological differences due to metal concentrations among lakes. The physical variables of greatest concern with regard to benthic community structure were depth and sediment TOC, because both can profoundly influence community structure in lakes and both varied relatively widely from site to site. Furthermore, TOC is related to metal speciation in sediments. Therefore, these habitat variables were included as covariates in the statistical comparisons of lakes, where appropriate (see Section 2.3.1.5 for the procedure used to select covariates).

Benthic Community Analysis

There were no readily apparent differences in community composition between the reference lakes and the exposed lakes that would suggest a metal-related effect on the benthos. A total of 68 benthic taxa were identified in the samples collected at lake sites. Lake benthic communities consisted largely of chironomid midge larvae (Chironomidae), oligochaete worms (Oligochaeta), nematode worms (Nematoda), mussels (Bivalvia) and snails (Gastropoda), which together accounted for about 80% of total abundance (Figure 2.3-3). Percentages of these groups varied considerably within each lake, with the exception of Consecon Lake. In this lake, all three sites were strongly dominated by chironomids and other groups were nearly absent. Of the other lakes, the benthic fauna of Round Lake (a reference lake) appeared most variable at this coarse level of examination, largely due to varying abundances of bivalves and oligochaetes. Statistical comparisons of % Oligochaeta and % Chironomidae among lakes found a significant difference in % Oligochaeta between Consecon Lake and each exposed lake (Tables 2.3-6 and 2.3-7). Chironomidae percentage did not vary significantly among lakes.

The variation in total abundance was not influenced by metal concentrations. Total invertebrate abundance ranged between 1500 (ML-2, ML-3, CL-2) and 7000 (CL-1) individuals per square metre, based on site means (Figure 2.3-3). Total abundance varied widely within lakes and no significant differences were found among lakes (Table 2.3-6). The sites in Consecon Lake (the reference lake with the lowest sediment metal concentrations) encompassed nearly the entire range in total abundance observed during this survey.

The richness data suggested that the number of taxa might have been reduced by sediment metal concentrations in Moira Lake and possibly in Bend Bay (Figure 2.3-3). Mean richness (mean of the three replicate samples at a site) ranged from 3 (ML-3) to 19 (SL-3) and total richness (all taxa found at a site) varied from 5 (ML-3) to 28 (CL-1). Ranges in both mean and total richness were similar in Consecon, Round and Stoco lakes. However, the maximum richness (14 taxa) in Moira Lake and Bend Bay was only slightly greater than the minimum value (12) in the reference lakes. Total richness was significantly lower in Moira Lake relative to Consecon Lake, but not when compared with Round Lake, and mean richness did not vary significantly among lakes (Tables 2.3-6 and 2.3-7). Within Moira Lake, the pattern in richness (i.e., lowest values at ML-3 and ML-4) did not reflect the sediment metal concentrations (generally higher concentrations at ML-1 to ML-3 than at ML-4 and ML-5; Figure 2.3-1). Thus, the significantly lower total richness suggested a metal-related effect in Moira Lake, but the pattern in richness within this lake did not correspond with metal concentrations in the sediments.

Figure 2.3-3
Total Invertebrate Abundance, Taxonomic Richness and Proportions of Major Invertebrate Groups at Lake Sites, Moira River System, Spring 1999

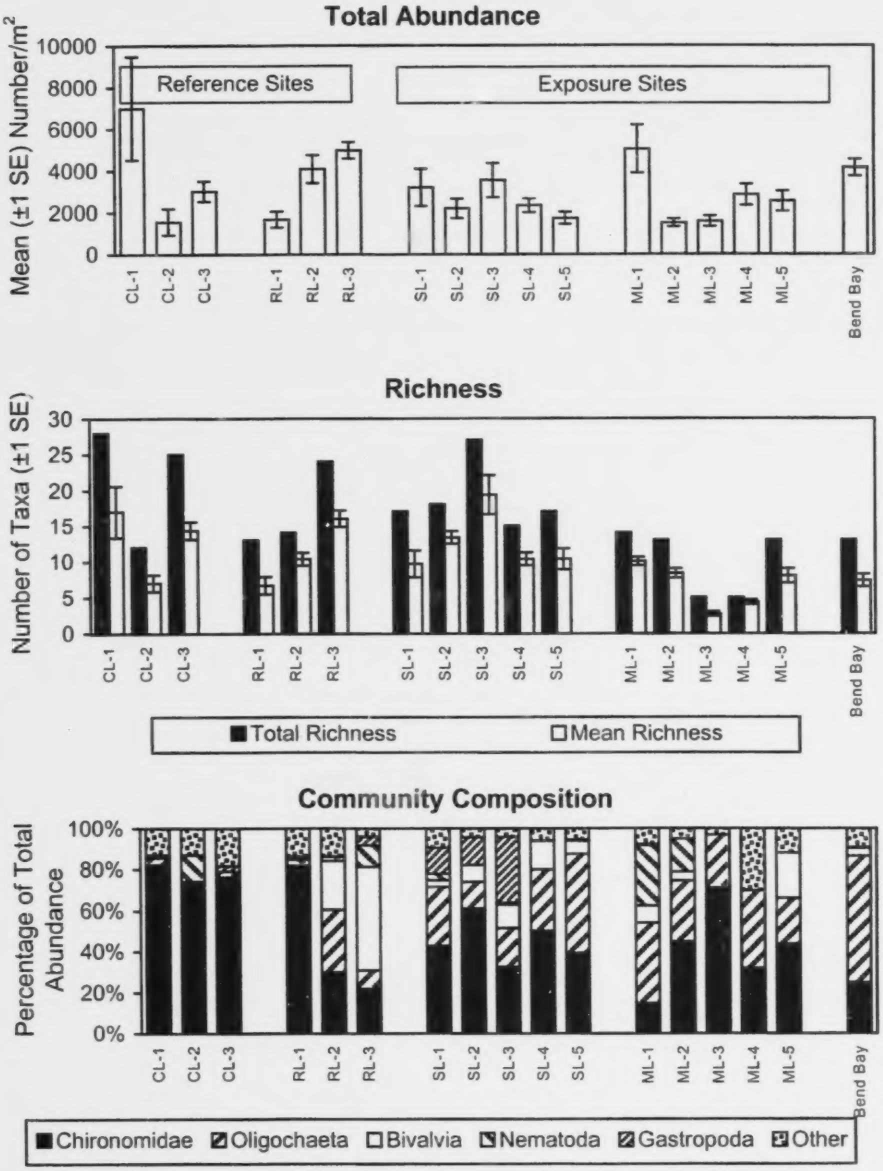


Table 2.3-6
Results of Overall ANOVA and ANCOVA Tests Comparing Benthic Community Variables Among Lakes, Moira River System, Spring 1999

Variable	ANOVA(a)(b)	ANCOVA(b)(c)		
	Mean	Covariate	Slope	Intercept
Taxonomic richness (total taxa/site)	-(e)	water depth	0.434	0.029
Taxonomic richness (mean no. of taxa/site)	-	water depth	0.402	0.119
Total invertebrate abundance	0.795	-	-	-
Oligochaeta abundance	0.129	-	-	-
% Oligochaeta (% of total abundance)	0.006	-	-	-
Tubificidae abundance	0.075	-	-	-
Limnodrilus spp. abundance(d)	0.021	-	-	-
Chironomidae abundance	0.027	-	-	-
% Chironomidae (% of total abundance)	0.101	-	-	-
% Chironomini (% of total Chironomidae)	0.013	-	-	-
% Tanypodinae (% of total Chironomidae)	0.015	-	-	-
% Tanytarsini (% of total Chironomidae)	-	water depth	0.531	0.0008
Chironomus abundance	0.040	-	-	-
Tanytarsini abundance	-	water depth sediment TOC	0.702 0.421	0.002
Cladopelma abundance	0.265	-	-	-
Metal-sensitive invertebrate abundance	-	water depth	0.291	0.0002
Metal-tolerant invertebrate abundance	0.0002	-	-	-
% Metal-sensitive invertebrates	0.006	-	-	-
% Metal-tolerant invertebrates (d)	0.004	-	-	-

(a) Probability value for testing an overall difference among means.
(b) Total degrees of freedom (d.f.) = 15, except for tests of *Limnodrilus* spp. abundance and %, where d.f.=14
(c) Probability value for testing an overall difference among slopes and intercept means.
(d) One outlier was removed.
(e) No result; test not carried out.

Table 2.3-7
Results of Tukey's Tests Comparing Benthic Community Variables Among Lakes for Variables with Significant ANOVA or ANCOVA Results, Moira River System, Spring 1999

Variable	Consecon *vs* Round		Reference Lakes *vs* Stoco Lake			Reference Lakes *vs* Moira Lake		
	P-value[a]	% Difference[b]	Reference Lake	P-value	% Difference	Reference Lake	P-value	% Difference
Taxonomic richness (total taxa/site)	0.657	-21	Consecon	0.660	-19	Consecon	0.027	-53
			Round	0.999	3	Round	0.220	-41
% Oligochaeta (% of total abundance)	0.544	517	Consecon	0.016	1835	Consecon	0.008	2109
			Round	0.204	214	Round	0.116	258
Limnodrilus spp. abundance[c]	0.661	-87	Consecon	0.575	479	Consecon	0.139	2589
			Round	0.096	4502	Round	0.018	21272
Chironomidae abundance	0.179	-51	Consecon	0.067	-55	Consecon	0.018	-64
			Round	0.986	-9	Round	0.704	-27
% Chironomini (% of total Chironomidae)	0.078	226	Consecon	0.962	-31	Consecon	0.880	-45
			Round	0.019	-79	Round	0.012	-83
% Tanypodinae (% of total Chironomidae)	0.606	-63	Consecon	0.262	97	Consecon	0.251	98
			Round	0.026	433	Round	0.025	436
% Tanytarsini (% of total Chironomidae)	0.004	-86	Consecon	0.0008	-92	Consecon	0.002	-86
			Round	0.913	-41	Round	1	-4
Chironomus abundance	0.725	331	Consecon	0.331	-90	Consecon	0.428	-86
			Round	0.052	-98	Round	0.073	-97
Tanytarsini abundance	1	-8	Consecon	0.010	-95	Consecon	0.091	-91
			Round	0.110	-94	Round	0.086	-90
Metal-sensitive invertebrate abundance[c]	0.810	-30	Consecon	0.001	-88	Consecon	0.001	-88
			Round	0.005	-83	Round	0.003	-83
Metal-tolerant invertebrate abundance	0.001	-83	Consecon	0.999	4	Consecon	0.990	-9
			Round	0.0003	530	Round	0.0005	452
% Metal-sensitive invertebrates	0.744	-23	Consecon	0.002	-87	Consecon	0.002	-84
			Round	0.010	-83	Round	0.015	-79
% Metal-tolerant invertebrates[c]	0.029	-83	Consecon	0.653	34	Consecon	1	-1
			Round	0.002	678	Round	0.021	476

[a] P-values are from Tukey's pairwise comparisons (following a significant ANOVA/ANCOVA F-statistic).

[b] % Difference is for exposed relative to the reference lake (or Round Lake relative to Consecon Lake) calculated using ANOVA/ANCOVA adjusted least squared means.

[c] One outlier was removed.

Visual examination of oligochaete abundances suggested the potential for subtle effects of sediment metal concentrations. Oligochaete numbers were generally higher in the exposed lakes and were particularly high in Bend Bay, but there was no overall significant difference among lakes (Figure 2.3-4, Table 2.3-6). In particular, the family Tubificidae, which included two genera (*Tubifex* and *Limnodrilus*) with common metal-tolerant species, was more numerous at Moira River system sites than at most sites in reference lakes. Despite this apparent trend, the among-lake variation in Tubificidae abundance was not significant (P = 0.075; Table 2.3-6).

The chironomid abundance data also provided only limited evidence of effects in the exposed lakes. A significant difference was found in total chironomid abundance between Consecon Lake and Moira Lake (the lakes with the lowest and highest metal concentrations), but not in any of the other comparisons (Figure 2.3-4, Tables 2.3-6 and 2.3-7). Differences among lakes and Bend Bay in the percentage of major chironomid groups were consistent with their relative sensitivities. The order of sensitivity for these groups is Orthocladiinae < Tanypodinae < Chironomini < Tanytarsini (in order of increasing sensitivity; based on information summarized by Clements 1991). In the lake data set, the highly sensitive Tanytarsini were nearly absent from all lakes except for Consecon Lake, which had the lowest metal concentrations. The percentage of the moderately sensitive Chironomini was lower in the exposed lakes than in the reference lakes. The percentage of the moderately tolerant Tanypodinae was higher in the exposed lakes (Figure 2.3-4). The percentages of these groups relative to total chironomids varied significantly among lakes in the overall ANOVA (Table 2.3-6). Significant pairwise differences were found in % Tanytarsini between Consecon Lake and each of the other lakes, and in % Tanypodinae and % Chironomini between Round Lake and the two exposed lakes (Table 2.3-7).

Visual examination of the abundances of common invertebrate groups and individual taxa also provided limited evidence of metal-related effects. Of the 27 taxa examined, a handful exhibited spatial patterns consistent with metal concentration. In most cases, these patterns were consistent with the reported sensitivity of these organisms. Taxa that appeared sensitive to metals included total mayflies (Ephemeroptera), *Hyalella azteca*, *Chironomus*, Tanytarsini and *Tribelos* (Figure 2.3-5). These invertebrates occurred in low numbers or were absent in Moira Lake and Bend Bay, occurred in variable numbers in Stoco Lake and were more abundant in at least one of the reference lakes. Clements (1991) and Mance (1987) have identified mayflies, crustaceans in general and Tanytarsini midges as sensitive. The two chironomid genera *Chironomus* and

Tribelos are members of the Tribe Chironomini, which has been shown to be moderately sensitive to copper (Clements 1991).

Figure 2.3-4
Abundances of Oligochaeta and Chironomidae at Lake Sites, Moira River System, Spring 1999

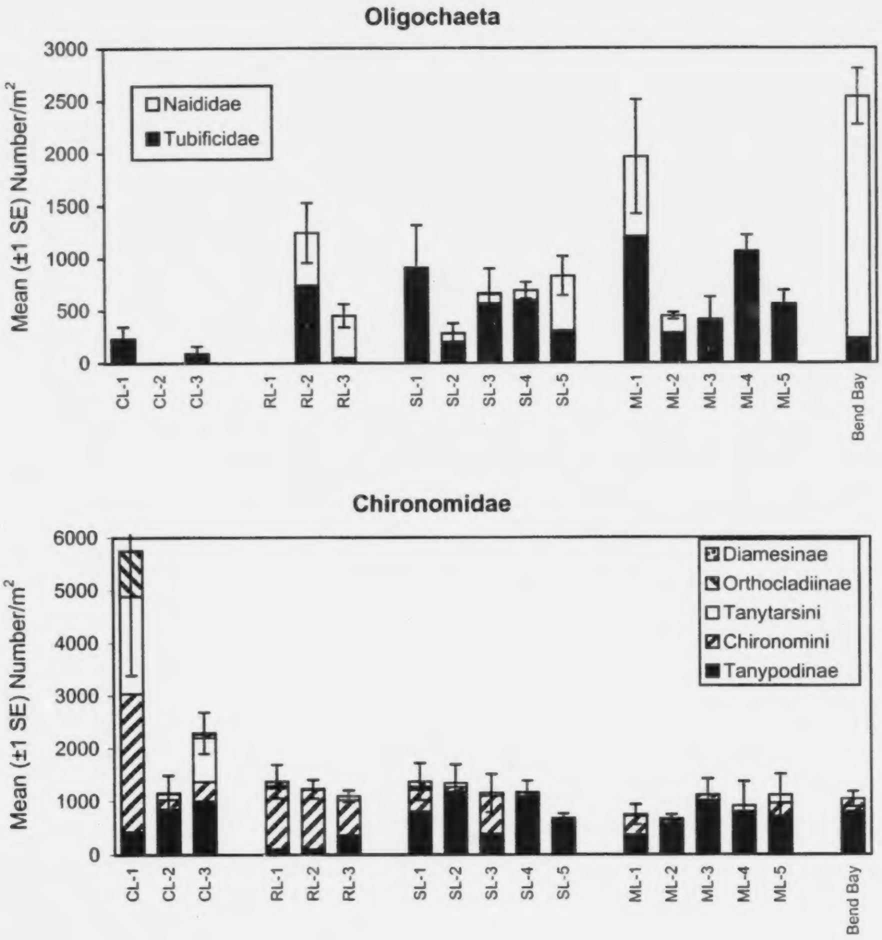
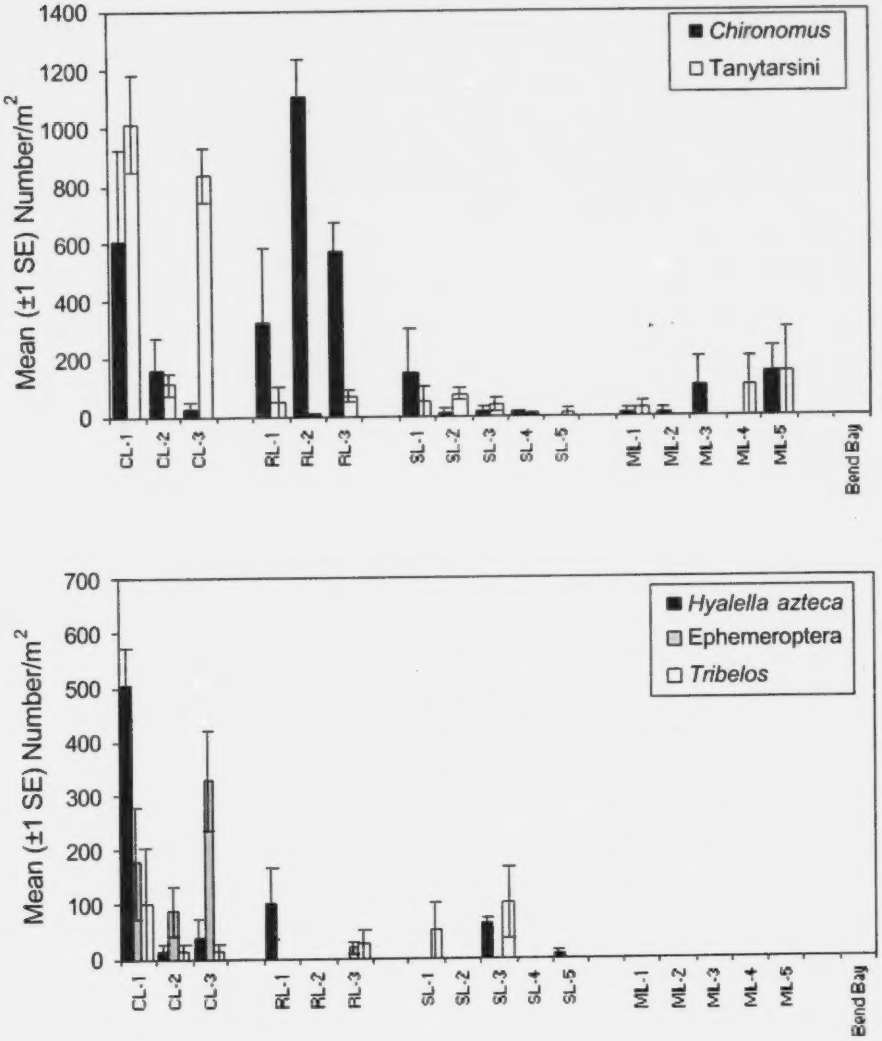
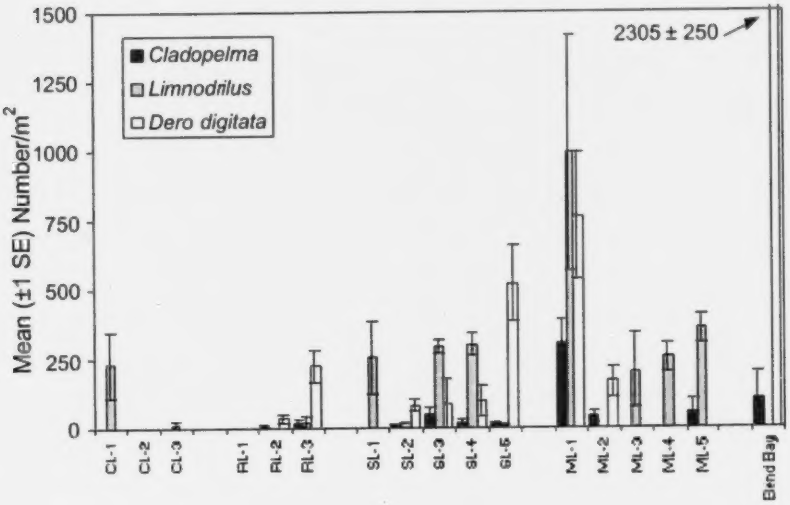


Figure 2.3-5
Abundances of Ephemeroptera, *Hyalella azteca*, *Chironomus*, Tanytarsini and *Tribelos* at Lake Sites, Moira River System, Spring 1999



Very few taxa showed the opposite pattern (e.g., *Limnodrilus*, *Cladopelma*, *Dero digitata*, Figure 2.3-6). Clear examples of tolerance, exhibited in an increase in abundance at polluted sites, were not apparent in the lake data set, but *D.digitata* was very abundant in Bend Bay. Of the taxa showing some tolerance, *Limnodrilus* has at least one known tolerant species (*L. hoffmeisteri*) (Clements 1991), but *Cladopelma* is a member of the generally sensitive Chironomini and there is no information on the metal-tolerance of *D. digitata* (a naidid worm).

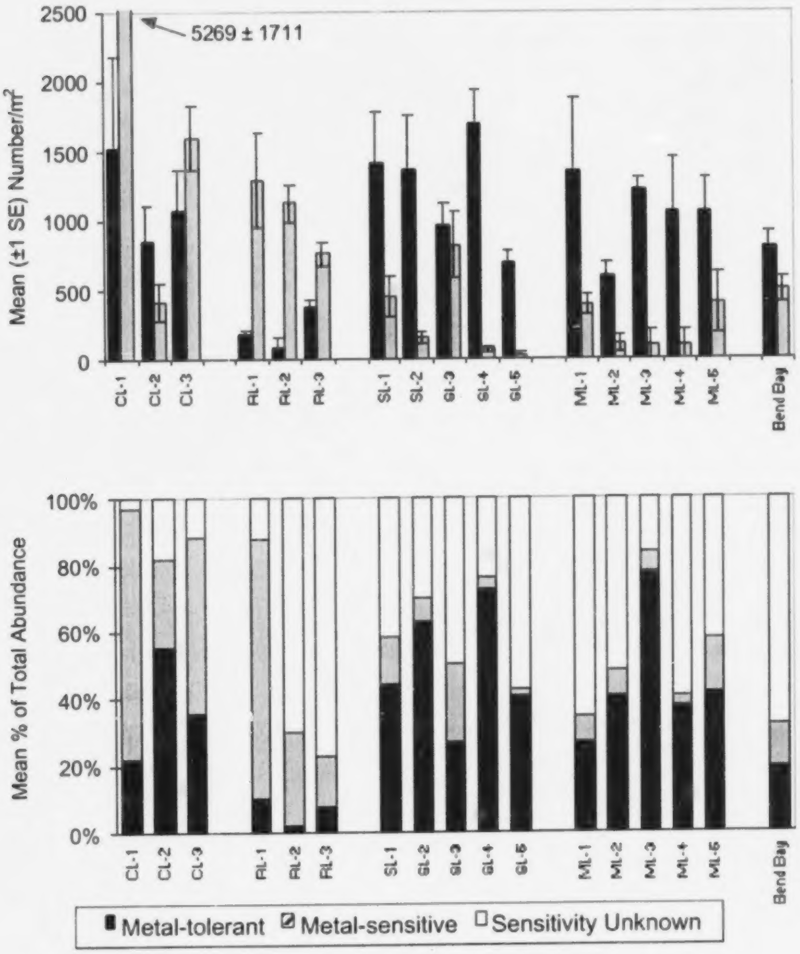
Figure 2.3-6
Abundances of *Limnodrilus*, *Dero digitata*, and *Cladopelma* at Lake Sites



Statistical comparisons of the abundances of these organisms were only possible for *Chiromonus*, Tanytarsini, *Cladopelma* and *Limnodrilus*, because the remaining taxa were present at fewer than three sites in most lakes. All but *Cladopelma* varied significantly among lakes (Table 2.3-6), but significant pairwise differences between the exposed lakes and both reference lakes were not found (Table 2.3-7).

The combined abundance and percentage of metal-sensitive invertebrates was reduced in the exposed lakes relative to the reference lakes (Figure 2.3-7), and the differences between each reference lake and both exposed lakes were statistically significant (Table 2.3-7). The trends for metal-tolerant taxa were less pronounced, largely because Consecon Lake communities included a moderate proportion of tolerant taxa. As a result, both the abundance and percentage of metal-tolerant taxa differed significantly between the two reference lakes, and the exposed lakes were significantly different only from Round Lake (Table 2.3-7).

Figure 2.3-7
Abundances and Percentages of Metal-sensitive and Metal-tolerant Invertebrates at Lake Sites, Moira River System, Spring 1999



In summary, examination of the lake benthos data and univariate analysis detected some trends in benthic community structure that were consistent with the effects of elevated metal concentrations, but these effects were subtle. Total abundance was not affected by metal concentrations in the exposed lakes, and richness was only reduced in Moira Lake. Despite the trends apparent upon visual examination of the data, statistical tests rarely detected significant differences between the exposed lakes and both reference lakes, which was largely the function of low statistical power in the pairwise tests. However, the abundance and percentage of metal-sensitive invertebrates were significantly reduced in both exposed lakes and were also reduced in Bend Bay relative to both reference lakes. In addition, the among-lake variation in abundances of a number of individual taxa was consistent with the relative metal-sensitivities of the taxa.

Results of the benthic community survey indirectly confirmed the suitability of Round Lake as a reference lake. Differences in dissolved oxygen profiles between Round Lake and the other three lakes (Appendix I) were of some concern during the analysis, because oxygen depletion occurred at the sediment-water interface in Consecon, Stoco and Moira lakes, but not in Round Lake. Based on the statistical analysis (Table 2.3-7), the number of biological variables that differed significantly between the study lakes and either reference lake were about equal and the corresponding % differences from each reference lake mean were similar. Thus, the study lakes differed about equally from each reference lake (despite the occasional significant difference between the reference lakes), thereby confirming the suitability of Round Lake as a reference lake.

Statistical Power

The power of the non-significant statistical tests was generally low (Table 2.3-8), as may be expected based on the low number of sites (replicates) in each lake. Considering power ≥ 0.80 as sufficient, only one of the non-significant tests (% Chironomidae) had sufficient power to detect a 50% difference in means and two had sufficient power to detect a 100% difference.

Multivariate Analysis

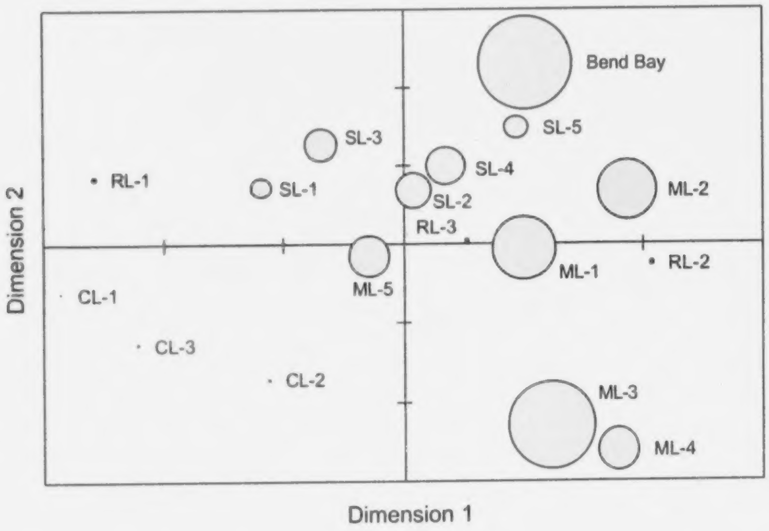
Ordination of the lake benthos data showed separation of Consecon Lake communities from those of other lakes, but Round Lake sites were widely separated from each other (Figure 2.3-8). The stress of the final configuration was 0.17, which represents "fair" fit of the results to the input data in qualitative terms (Clarke 1993). There was a general trend from reference to exposed sites along Dimension 1, as illustrated for arsenic in Figure 2.3-8 (larger symbols represent sites with higher arsenic concentrations). Arsenic was used to represent sediment chemistry because it was one of the most toxic substances released from the former Deloro Mine Site, and its concentration in sediment was correlated with those of all other metals of concern, with the exception of lead.

Table 2.3-8
Statistical Power to Detect Differences of 20, 50 and 100% (ES, effect size) for Comparisons That Did Not Detect Significant Differences, Lake Habitat, Moira River System, Spring 1999

Variable	ES=20%	ES=50%	ES=100%
Taxonomic richness (mean no. of taxa/site)	0.15	0.69	1
Total invertebrate abundance	0.07	0.18	0.47
Oligochaeta abundance	0.05	0.06	0.07
Tubificidae abundance	0.05	0.06	0.08
% Chironomidae (% of total abundance)	0.30	0.98	1
Cladopelma abundance	0.05	0.06	0.08

Note: Power was based on ANOVA/ANCOVA model including all four lakes.

Figure 2.3-8
Ordination Plot of Lake Sites, Moira River System, Spring 1999
(Areas of symbols are proportional to arsenic concentration in sediment)



Seven of the eleven taxa with significant correlations to Dimension 1 were designated as metal-sensitive in this study or belong to a generally metal-sensitive group, two were metal-tolerant and sensitivity of the remaining two taxa is unknown (Table 2.3-9). All metal-sensitive taxa and both tolerant taxa were negatively correlated with Dimension 1. There was no consistency in the metal-sensitivity of taxa correlated to Dimension 2.

Table 2.3-9
Spearman Rank Correlations Between NMDS Dimensions, Physical Factors and Abundances of Common Invertebrates at Lake Sites, Moira River System, Spring 1999 (n=17; significant correlations [p<0.05] are identified by bolded coefficients)

Variable[a]	Dimension 1	Dimension 2
Physico-chemical Variables		
Sediment Chemistry (PC1)	**0.745**	0.103
Water depth	0.433	-0.380
% fine sediments	0.002	0.091
Sediment TOC	0.442	0.179
Benthic Invertebrate Taxa		
Ilyodrilus templetoni	**0.786**	-0.476
Psectrocladius (T)	**-0.719**	-0.285
Hyalella azteca (S)	**-0.714**	0.029
Tanytarsus (S)	**-0.684**	-0.442
Tribelos (S)	**-0.625**	-0.068
Hexagenia limbata (S)	**-0.571**	-0.466
Glyptotendipes (S)	**-0.560**	-0.018
Coelotanypus (T)	**-0.556**	-0.474
Polypedilum (S)	**-0.532**	0.143
Parachironomus (S)	**-0.525**	-0.333
Viviparus georgianus	**-0.516**	-0.337
Dero digitata	0.480	**0.633**
Tubifex tubifex (T)	-0.199	**0.595**
Cladopelma (S)	0.379	**0.521**
Acarina	0.242	**-0.519**

[a] T = metal-tolerant; S = metal-sensitive.

The communities of sites RL-2 and RL-3 did not "fit" the general trend along the metal concentration gradient (Figure 2.3-8). Sediments at one of these sites (RL-2) contained lead at a concentration (140 µg/g) that exceeded the Ontario lowest effect level guideline (31 µg/g), which may account for the position of this site on the ordination plot. However, there is no obvious explanation for the unusual community at RL-3, where sediment metal concentrations were similar to those at RL-1. At RL-3, the major difference in community structure was contributed by the dominance of bivalves, which accounted for >50% of total abundance.

Correlation analysis between environmental variables and NMDS dimensions found that sediment chemistry PC1 was significantly positively correlated with Dimension 1 (Table 2.3-9). Other environmental variables were not significantly correlated with either dimension. Thus, the positive correlations between sediment metal concentrations and Dimension 1 (which is generally negatively correlated with abundances of metal-sensitive taxa) were consistent with the expected trend in community structure with increasing sediment concentrations. Overall, results of the ordination support the interpretation that there was a shift in benthic community structure in lakes in response to sediment metal concentrations.

Sediment Quality Triad (SQT)

This section attempts to integrate information from each SQT component by examining the relationships among the biological, chemical and toxicological data. Concordance among these data sets was evaluated using correlation analysis of major patterns in each data set, as summarized by separate ordinations.

The biological data set was summarized as Dimensions 1 and 2 generated by NMDS. Two additional major community descriptors, total abundance and richness, were also included in the triad analysis to allow greater depth of interpretation. Only PC1 was used to represent the chemistry data set, because four of the metals (i.e., arsenic, cobalt, copper and nickel) had high loadings on this component and PC1 explained most of the variance in the chemistry data set (Table 2.3-10). Although silver was not included in the chemistry PCA, it was strongly correlated with PC1. Chemistry PC2 largely represented lead, which was not necessarily contributed by the former Deloro Mine Site, as indicated by elevated lead concentrations in Round Lake (a reference lake) sediments.

The first two PCs were used to represent the toxicity data set, because they both accounted for large proportions of the overall variance (Table 2.3-10). None of the four tests on lake sediments detected appreciable toxicity, with the possible exception of the reduction in *H. azteca* weight at two sites in Moira Lake and reductions of *C. riparius* survival in Consecon and Moira lakes (Table 2.3-11).

Table 2.3-10
Summary of the Sediment Chemistry and Toxicity PCAs, Lake Habitat, Moira River System, Spring 1999

Data Set and Variable	PC1	PC2
Sediment Chemistry (component loadings)		
Copper	0.977	-0.022
Cobalt	0.973	0.211
Nickel	0.962	0.195
Arsenic	0.941	0.110
Lead	0.587	-0.808
Silver	(0.914)[a]	(0.336)[a]
Eigenvalue	4.059	0.748
Variance Explained (%)	81.2	15.0
Sediment Toxicity (component loadings)		
Hyalella azteca survival	0.822	-0.043
Hyalella azteca weight	0.816	0.275
Chironomus riparius survival	0.106	0.937
Chironomus riparius weight	0.704	-0.410
Eigenvalue	1.850	1.123
Variance Explained (%)	46.2	28.1

[a] Pearson correlation between silver concentrations and PC scores; silver was not included in the PCA due to missing data.

Table 2.3-11
Sediment Toxicity Data Set, Lake Habitat, Moira River System, Spring 1999

Lake	Site	*H. azteca* Survival (% control)	*H. azteca* Weight (% control)	*C. riparius* Survival (% control)	*C. riparius* Weight (% control)
Consecon	CL1	102	96	100	136
	CL2	104	80	76	162
	CL3	96	98	67	151
Round	RL1	93	123	109	107
	RL2	104	100	96	91
	RL3	100	89	82	79
Stoco	SL1	104	118	93	119
	SL3	109	117	87	136
	SL4	107	120	89	154
Moira	ML1	93	51	88	77
	ML4	91	69	93	116
	ML5	98	91	67	83
Moira River	Bend Bay	102	86	102	106

Significant correlations among the SQT components were limited to those between the biological and chemical data (Table 2.3-12). Richness of the benthic community declined and site scores on benthos Dimension 1 increased with increasing metal concentrations (Chemistry PC1), suggesting a metal-related shift in benthic community structure. The additional significant correlations were inter-correlations within the biological data set. The lack of significant correlations between the toxicity data and the other data sets is not surprising, in light of the general absence of toxicity of the sediments tested in the laboratory.

Table 2.3-12
Spearman Rank Correlations Among SQT Components,
Lake Habitat, Moira River System, Spring 1999
(Significant correlations [$P < 0.05$] are identified by bolded coefficients; n=17, except for correlations with toxicity variables, where n=13)

Data Set	Chemistry PC1	Toxicity PC1	Toxicity PC2	Benthos Abundance	Benthos Richness	Benthos Dim. 1	Benthos Dim. 2
Chemistry PC1	1	-	-	-	-	-	-
Toxicity PC1	-0.495	1	-	-	-	-	-
Toxicity PC2	0.341	-0.137	1	-	-	-	-
Benthos – Abundance	-0.218	-0.242	0.313	1	-	-	-
Benthos – Richness	**-0.646**	0.445	-0.144	**0.531**	1	-	-
Benthos – Dimension 1	**0.745**	-0.412	0.159	-0.088	**-0.490**	1	-
Benthos – Dimension 2	0.103	0.275	0.352	0.054	0.321	-0.074	1

The SQT analysis produced generally similar results to other analyses; i.e., there is some indication of a relationship between metal concentrations and the benthic invertebrate community, but this relationship is not pronounced.

2.3.2.2 River Habitat

Variation in Habitat

Field measurements revealed large differences in water depth and sediment TOC among sites and low to moderate variation in sediment particle size (Table 2.3-13). Conductivity was within a reasonably narrow range at most sites (150 to 250 µS/cm), with the exception of two sites where the minimum (50 µS/cm; SKR-1) and maximum (330 µS/cm; MR-13) values were measured. Water temperature was similar at all sites in the Moira River (10 to 15°C), but was higher in the reference rivers (17 to 20°C). Since the reference rivers were sampled a few days later than the Moira River, variation in air temperature is the most likely source of this difference.

Table 2.3-13
Variation in Field Water Quality Parameters, Depth and Sediment Particle Size Among River Sites

Site	Water Depth (m)	Conductivity (µS/cm)	Water Temp. (°C)	Sediment Characteristics			
				Clay (wt. %)	Silt (wt. %)	Sand (wt. %)	TOC (wt. %)
Black River							
BR-1	0.25-0.5	139	18.0	3.5	21	65	3.3
Skootamatta River							
SKR-1	0.25-0.5	50	17.0	6.4	35	57	2.4
Salmon River							
SR-1	0.25-0.5	190	19.4	7.0	42	40	16.0
SR-2	0.25-0.5	163	19.3	8.6	46	35	9.3
SR-3	0.25-0.5	129	20.0	14.2	47	39	5.4
Moira River							
MR-1	0.5	226	12.4	5.0	29	66	0.8
MR-3	0.25-0.5	no data	no data	7.4	43	49	3.0
MR-5	1.5	225	12.4	7.8	53	39	3.2
MR-6	0.25-0.5	231	14.9	7.7	52	38	3.2
MR-7	0.6	230	14.3	6.2	40	54	3.8
MR-8	0.6	228	13.6	6.3	39	55	2.6
MR-9	1.0	256	14.4	7.1	50	43	12.0
MR-10	3.5	257	11.8	8.3	54	38	14.0
MR-12	3.5	168	13.4	6.5	40	54	3.3
MR-13	1.5	330	10.2	8.4	57	34	14.0
MR-14	1.0	199	12.0	6.5	34	48	3.8
MR-15	1.3	222	13.1	3.1	22	75	1.7
Young's Creek							
YC-1	3.0	no data	no data	11.3	67	22	15.0

The variation in the physical attributes of sampling sites was sufficient to account for part of the variation in benthic community structure. As in the lake data set, the physical variables of greatest concern were water depth and sediment TOC, because both varied widely. The greater depth at two sites (3.5 m; MR-10 and MR-12) may complicate the data analysis, because all other sites were up to 1.5 m deep (the single Young's Creek site was also deeper than most sites, but was not included in the analysis). Initial examination of the benthos data suggested that depth was a significant factor at the two deep sites in the Moira River. Total abundance, richness and abundances of a number of individual taxa were low at these two deep sites relative to others, despite widely differing metal concentrations in the sediments (Figure 2.3-2). A similar effect was not apparent for sediment TOC, which had a strongly bimodal distribution (TOC was >10% at five sites; ≤5% at 12 sites and intermediate at only one site).

Habitat variation was taken into account during data analysis by using the important habitat variables (depth, TOC, sediment particle size) as independent variables in the regression analysis. Diagnostic tests were run and scatter-plots were checked for each variable to see if the deep sites or those with high TOC were acting as outliers, and that outliers were removed if warranted.

Benthic Community Analysis

The benthic communities of the river sites had higher species richness than lake communities. The river data set had a total of 117 taxa, compared to 68 taxa in the lake data set. Chironomid midges and oligochaete worms dominated the river benthic communities, though mollusks and amphipods occasionally accounted for a significant fraction of the total abundance at a site (Figure 2.3-9). At the level of major group, community composition was highly variable among the reference sites and among exposed sites.

Total invertebrate abundance was not influenced by mine-related sediment metal concentrations (Figure 2.3-9). Regression analysis detected no significant relationship between sediment metal concentrations and total abundance (Table 2.3-14). Similarly, abundance at the three lower Moira River sites did not differ significantly from those in the Salmon River (Table 2.3-15). The variation in total abundance within the Moira River appeared related to habitat attributes rather than sediment metal concentrations. Total abundance varied moderately, but without a noticeable trend from Sites MR-1 to MR-8 (Figure 2.3-9), despite a sharp increasing trend in sediment metal concentrations from Site MR-5 to MR-8 (Figure 2.3-2). Habitat characteristics of these sites were similar (Table 2.3-13). Conspicuously low total abundances were found at sites MR-9, MR-10 and MR-12. Two of these sites (MR-10 and MR-12) were more than twice as deep as all other sites. The greater depth most likely accounted for the low abundances at these sites since metal concentrations differed widely between them (Figure 2.3-2; note that these sites were excluded from the regression analysis because of this depth-effect). The remaining site in this reach with low total abundance (MR-9) had elevated metal concentrations (as did MR-7 and MR-8), but also had much higher sediment TOC than all upstream sites. Since high TOC did not limit abundance at other river sites (e.g., SR-1 and MR-13, both with low metal concentrations), there is no obvious explanation for the low abundance at MR-9.

Figure 2.3-9
Total Invertebrate Abundance, Taxonomic Richness and Proportions of Major Invertebrate Groups at River Sites, Moira River System, Spring 1999

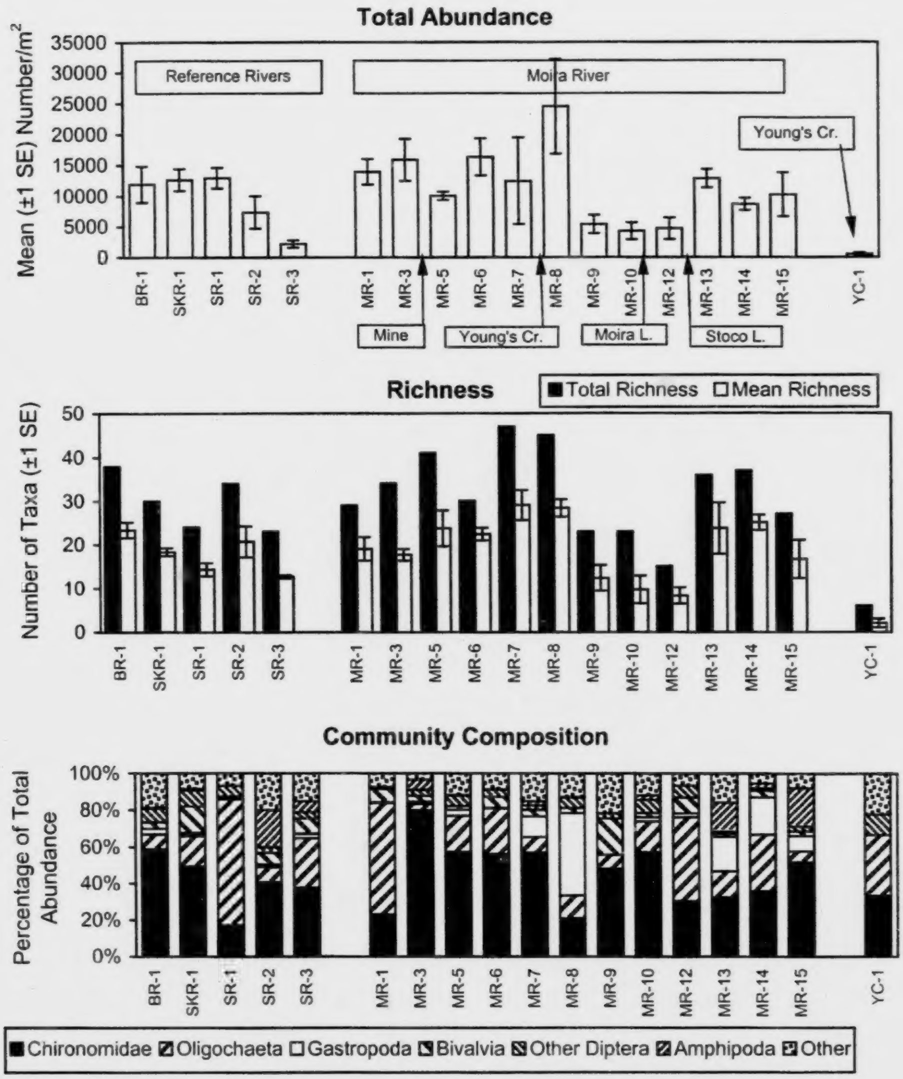


Table 2.3-14
Results of Linear Regressions Between Biological Variables and Environmental Variables at River Sites

Variable	n	Regression Coefficient	Constant	P-value	R^2
Taxonomic richness (total taxa/site)[a]	14	PC1[b]: 5.454	34.824	0.008	0.454
Taxonomic richness (mean no. of taxa/site)[a]	14	PC1: 3.903	21.688	0.004	0.521
Total invertebrate abundance	15	NS			
Oligochaeta abundance	15	NS			
% Oligochaeta (% of total abundance)	15	NS			
Tubificidae abundance	15	NS			
Aulodrilus pluriseta abundance	15	PC1: 0.990	1.215	0.002	0.525
Chironomidae abundance	15	NS			
% Chironomidae (% of total abundance)	15	NS			
Chironomini abundance	15	NS			
Tanytarsini abundance	15	TOC: -0.009	3.521	0.007	0.438
Orthocladiinae abundance	15	PC1: 0.422 TOC: -0.013	2.873	0.0004	0.728
Tanypodinae abundance	15	NS			
% Chironomini (% of total Chironomidae)	15	TOC: 0.298	22.592	0.009	0.420
% Tanytarsini (% of total Chironomidae)	15	Depth: -19.808 TOC: -0.237	61.622	0.026	0.457
% Orthocladiinae (% of total Chironomidae)	15	PC1: 4.377 TOC: -0.070	10.868	0.003	0.630
% Tanypodinae (% of total Chironomidae)	15	NS			
Dicrotendipes abundance	15	PC1: 0.487 Depth: 1.078	1.544	0.039	0.417
Conchapelopia abundance	15	PC1: 0.884	1.265	0.006	0.448
Cricotopus abundance[a]	14	TOC: -0.013	2.583	0.005	0.492
Caenis abundance	15	PC1: 0.823	1.699	0.005	0.467
Metal-sensitive invertebrate abundance	15	NS			
Metal-tolerant invertebrate abundance	15	NS			
% Metal-sensitive invertebrates	15	NS			
% Metal-tolerant invertebrates	15	NS			

[a] One outlier was removed.

[b] PC1 refers to scores on sediment chemistry Principal Component 1 (Table 2.3-17).

Table 2.3-15
Results of Paired t-tests Comparing Biological Variables Between the Salmon River and the Lower Moira River

Variable	Mean Difference (%)(a)	P-value
Taxonomic richness (total taxa/site)	25	0.156
Taxonomic richness (mean no. of taxa/site)	39	0.076
Total invertebrate abundance	130	0.369
Oligochaeta abundance	89	0.985
% Oligochaeta (% of total abundance)	39	0.514
Tubificidae abundance	145	0.992
Aulodrilus pluriseta abundance	67	0.189
Chironomidae abundance	213	0.260
% Chironomidae (% of total abundance)	38	0.339
Chironomini abundance	102	0.292
Tanytarsini abundance	693	0.185
Orthocladiinae abundance	1100	0.030
Tanypodinae abundance	1160	0.499
% Chironomini (% of total Chironomidae)	-19	0.358
% Tanytarsini (% of total Chironomidae)	129	0.189
% Orthocladiinae (% of total Chironomidae)	358	0.143
% Tanypodinae (% of total Chironomidae)	495	0.850
Dicrotendipes abundance	169	0.304
Conchapelopia abundance	67	0.227
Cricotopus abundance	717	0.042
Caenis abundance	67	0.351
Metal-sensitive invertebrate abundance	201	0.378
Metal-tolerant invertebrate abundance	142	0.695
% Metal-sensitive invertebrates	15	0.863
% Metal-tolerant invertebrates (c)	-6	0.642

(a) % Difference is for Moira River relative to the Salmon River.

The very low abundance and richness at the single site in Young's Creek (YC-1, not included in the statistical analysis) most likely resulted from high metal levels originating from the Deloro Mine Site. Effects in Young's Creek can be assessed qualitatively, by comparing the benthic fauna of YC-1 with that of MR-10. Both sites were deep (3-3.5 m) and had high sediment TOC (14-15 %), but differed widely in sediment metal concentrations in grab samples as shown below:

Element	MR-10 (µg/g)	YC-1 (µg/g)
Arsenic	260	3000
Cobalt	740	1600
Copper	100	3200
Lead	28	56
Nickel	470	1000
Silver	11	4
Uranium	0.89	19

The corresponding values in total abundance and richness of the benthic community were:

Variable	MR-10	YC-1
Total abundance (mean no./m^2)	4256	456
Richness (total taxa)	23	6

Clearly, the Young's Creek site supported a very poor fauna, even compared to another site with generally elevated metal concentrations (except for uranium). In terms of the entire river benthos data set, YC-1 had by far the lowest values for both abundance and richness, also suggesting a severe effect in Young's Creek (the ranges without YC-1 were 2,153 to 24,523 organisms/m^2 and 15 to 47 taxa). Moreover, toxicity of YC-1 sediment was pronounced with 100% mortality in *Hyalella azteca* and 86% mortality in *Chironomus riparius* (Appendix III). Therefore, based on a qualitative assessment, the benthos of YC-1 was severely affected by metals originating from the former Deloro Mine Site.

The trend in taxonomic richness along the Moira River generally reflected that in total abundance, with the exception that richness increased in a downstream direction in the upper Moira River (Figure 2.3-9). There was a significant positive relationship between sediment metal concentrations and richness (Table 2.3-14; significant regressions between PC1 and both richness variables), which was contrary to expectations. This result does not necessarily mean that increased metal concentrations resulted in increased numbers of taxa because the metals were largely in the more unavailable forms, such as the residual, oxides or organic fractions (Table 2.2-3). The lower Moira-Salmon River comparisons of richness did not detect significant differences (Table 2.3-15). Since richness is typically one of the most sensitive indicators of metal-related effects, the results of this study suggest that there is no indication of adverse effects. The low richness in Young's Creek was likely related to sediment metal concentrations; however, the sediments in Young's Creek were highly organic. Therefore, low oxygen concentrations may also have been a factor.

Abundances of chironomid midges and oligochaete worms also provided no consistent evidence of metal-related effects on the benthos of the Moira River. Both were highly variable among reference sites (Figure 2.3-10) and numbers did not clearly reflect habitat variation. Regression analysis found no significant relationships between sediment metal concentrations and numbers in either group, when expressed as abundance or percentage of total abundance (Table 2.3-14). The lower Moira-Salmon River comparisons also did not detect significant differences (Table 2.3-15).

The oligochaete fauna of the study area was strongly dominated by tubificid worms (Figure 2.3-10). Hence, results of the regression analysis and lower river comparisons for this group were nearly identical to those for total oligochaetes (Tables 2.3-13 and 2.3-14).

Within the Chironomidae, sediment TOC and, in one instance, water depth influenced abundances and percentages in all major subfamilies and tribes, except the Tanypodinae (Table 2.3-14). Both sediment metal concentrations and TOC significantly influenced the Orthocladiinae (Table 2.3-14). The direction of the relationship with sediment concentration (positive) was consistent with the tendency of the Orthocladiinae to increase in abundance at locations with increased metal concentrations (Clements 1991). Comparisons of the lower Moira River with the Salmon River found only one significant difference, also in Orthocladiinae abundance (Table 2.3-15). Mean abundance of this group was higher in the Moira River that the reference river. Since the Orthocladiinae represented a small component of the chironomid fauna, accounting for <20% of total chironomids at all sites, the effect of sediment metal concentrations on chironomids can only be considered minor. In contrast, both the chironomid and oligochaete fauna of Young's Creek were nearly eliminated by the high metal concentrations originating at the former Deloro Mine Site.

Visual examination of the abundances of common invertebrate groups and individual taxa also did not provide consistent evidence of effects. Of the 39 taxa examined, only five exhibited spatial patterns consistent with effects in the Moira River, beginning at Site MR-5 (Figure 2.3-11). These invertebrates occurred in low numbers or were absent at the reference sites, and increased in abundance below the former Deloro Mine Site. This pattern was not consistent with the reported metal-sensitivity of at least one of these organisms: *Caenis* is a member of a highly metal-sensitive invertebrate group (mayflies) and has also been identified by individual studies as sensitive to certain metals (Clements 1991).

Figure 2.3-10
Abundances of Oligochaeta and Chironomidae at River Sites, Moira River System, Spring 1999

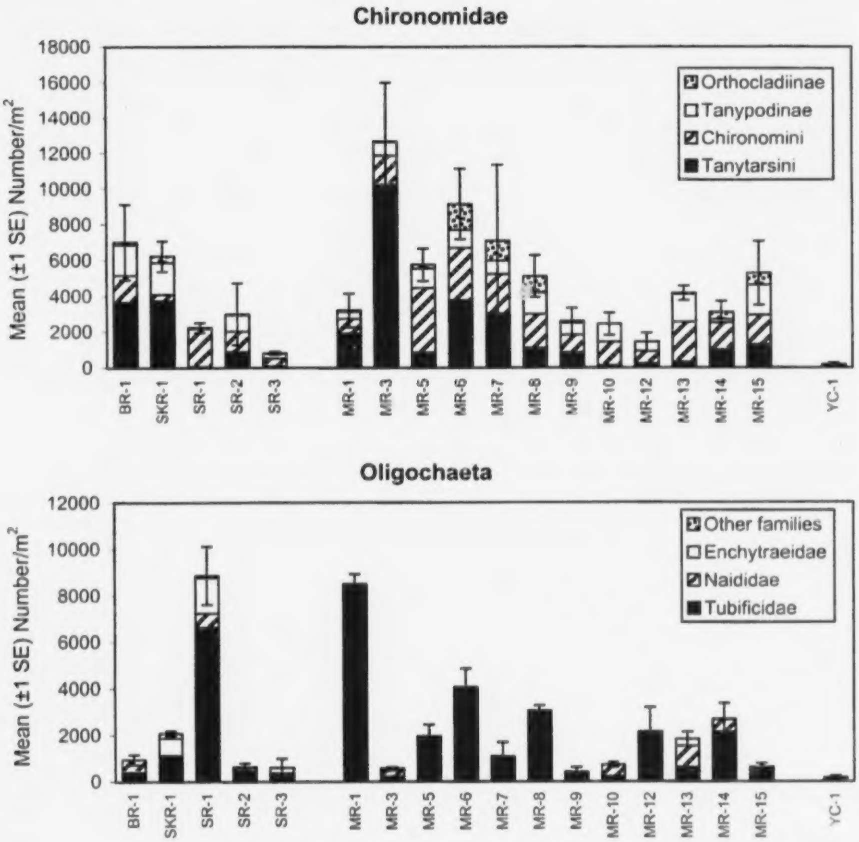
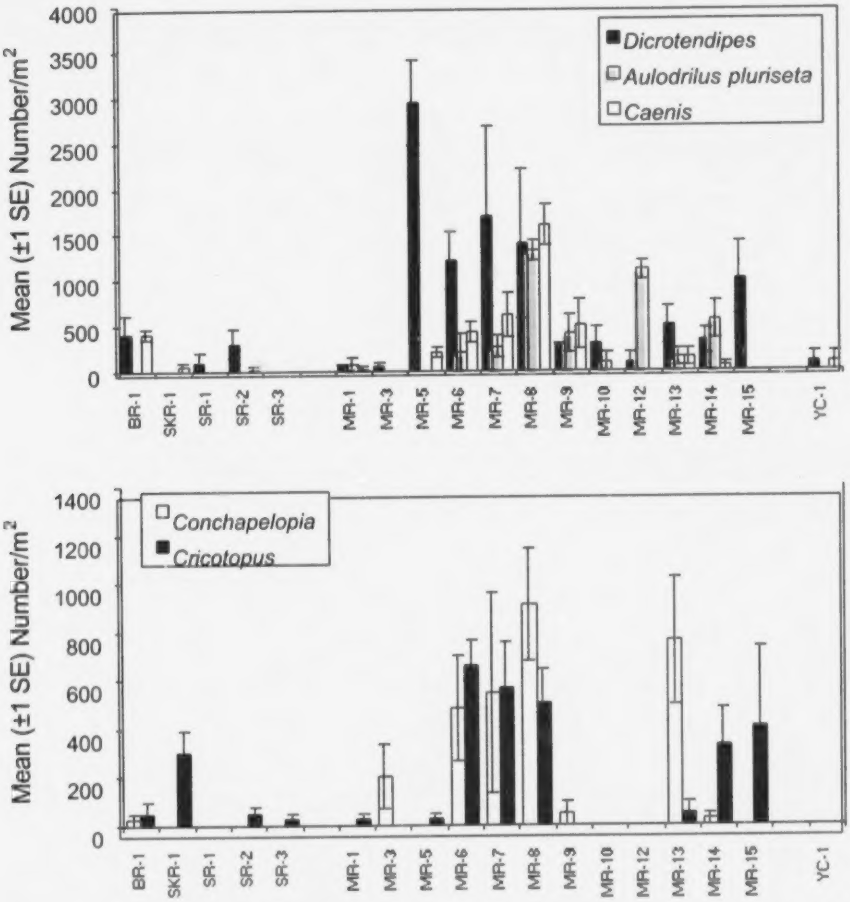


Figure 2.3-11

Abundances of *Aulodrilus pluriseta*, *Caenis*, *Dicrotendipes*, *Conchapelopia* and *Cricotopus* at River Sites, Moira River System, Spring 1999



Regression analysis detected significant positive relationships between sediment metal concentrations and abundances of four of the above five taxa (*A. pluriseta*, *Dicrotendipes*, *Conchapelopia*, *Caenis*; Table 2.3-14), but no differences were found between lower Moira River sites and the Salmon River reference sites (Table 2.3-15). Abundance of *Cricotopus* was negatively related to sediment TOC and was significantly higher in the lower Moira River than in the Salmon River despite similar TOC levels in both rivers.

The combined abundances and percentages of metal-sensitive and metal-tolerant invertebrates (Figure 2.3-12) were not significantly related to sediment metal concentrations or habitat variables (Table 2.3-14), and the lower Moira/Salmon River comparisons yielded non-significant results (Table 2.3-15).

Overall, examination of the river benthos data set using univariate methods did not provide a consistent indication of adverse effects on benthic community below the former Deloro Mine Site. Total abundance, richness and abundances of major invertebrate groups and metal-sensitive invertebrates were not adversely affected by elevated metal concentrations in bottom sediments, but rather tended to reflect habitat conditions. Abundances of a few individual taxa were significantly related to sediment metal concentrations, but in all cases abundances increased with increasing metal levels.

Multivariate Analysis

Ordination of the river benthos data did not show clear separation of communities along the metal concentrations gradient encompassed by the river data set, but also did not preclude a slight shift in community structure in response to sediment metal concentrations. The stress of the final configuration was 0.19, which represents a relatively poor fit to the input data; however, this level of stress does not preclude a useful description of patterns in the input data (Clarke 1993). Upper Moira River sites in similar habitat and with elevated sediment metal levels (MR-5 to MR-8) tended to cluster together, but the Black River reference site (BR-1) was also close to this group (Figure 2.3-13). Salmon River sites and lower Moira River sites each formed unique, but relatively heterogeneous groups. Ordering of sites along Dimension 1 suggested some correspondence between benthos community structure and sediment metal concentrations. The one conspicuous outlier, Site MR-10 was one of the 3.5 m deep sites, which supported unusual benthic communities relative to all other sites.

Figure 2.3-12
Abundances and Percentages of Metal-sensitive and Metal-tolerant Invertebrates at River Sites, Moira River System, Spring 1999

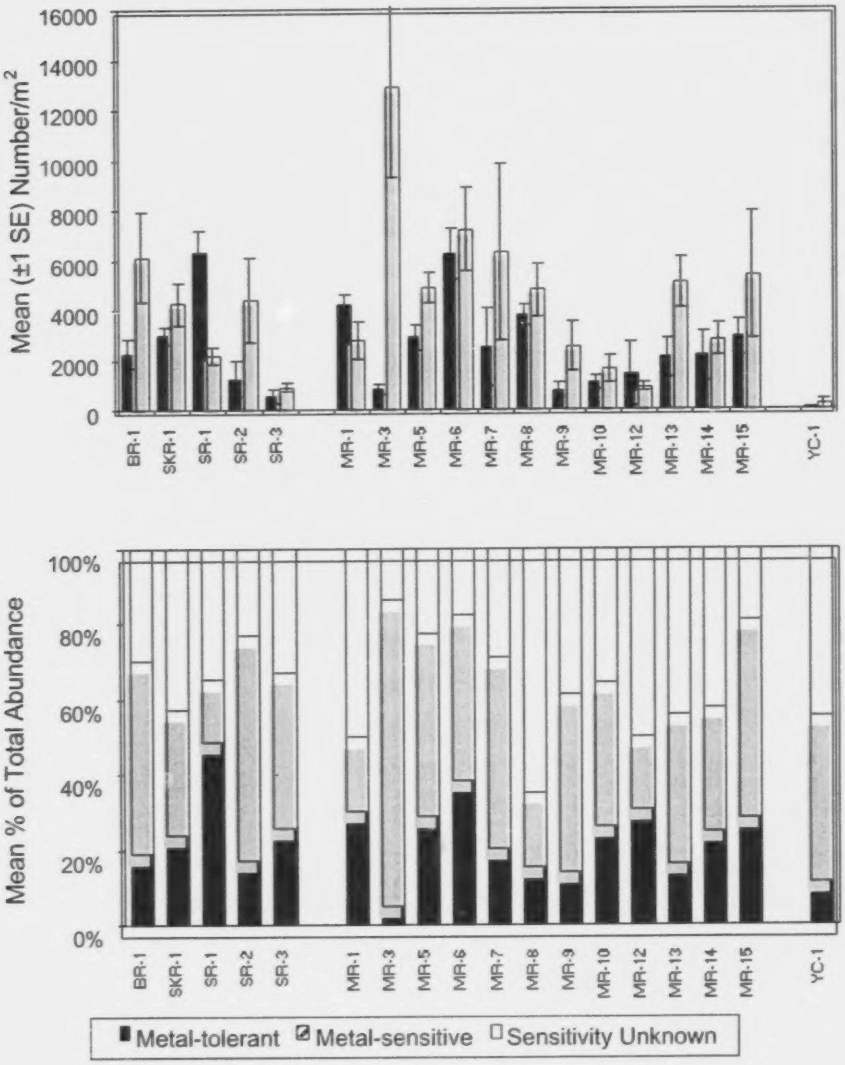
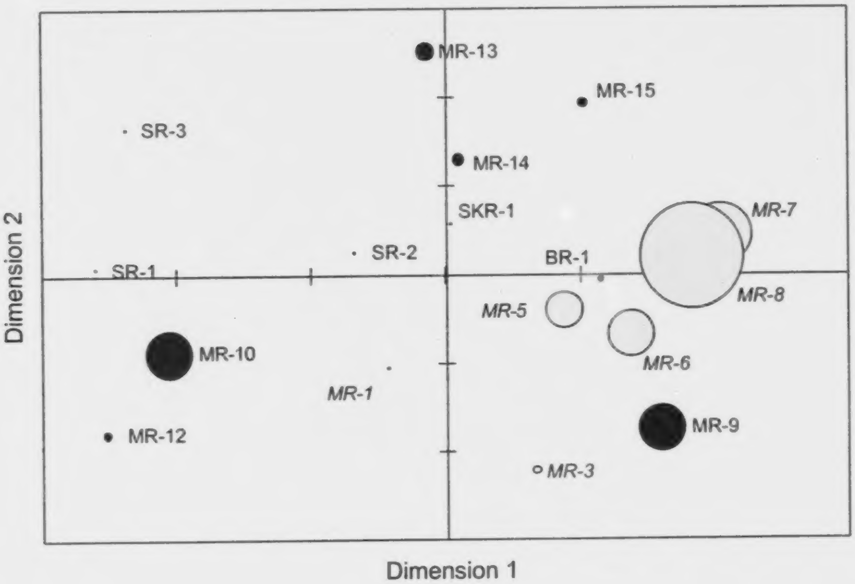


Figure 2.3-13
Ordination Plot of River Sites, Moira River System, Spring 1999
(Areas of symbols are proportional to arsenic concentration in sediment; upper Moira River sites in similar habitat are identified by light-shaded symbols and site labels in italics, all other sites are shown as black circles)



There was no consistency with regard to metal-sensitivity in the groups of taxa that were significantly correlated with either biological dimension (Table 2.3-16). Similarly, there were no significant correlations between environmental variables and either dimension. Overall, results of the ordination suggest the potential for a slight shift in benthic community structure in response to sediment metal concentrations, but the type of community shift does not lend itself to a simple interpretation based on metal-sensitivity of individual benthic taxa.

Table 2.3-16
Spearman Rank Correlations between NMDS Dimensions, Physical Factors and Abundances of Common Invertebrates at River Sites
(n=17; Significant correlations [p<0.05] are identified by bolded coefficients)

Taxon	Dimension 1	Dimension 2
Physico-chemical Variables		
Sediment Chemistry (PC1)	0.316	0.005
Water depth	-0.019	-0.043
% fine sediments	-0.262	-0.064
Sediment TOC	-0.362	0.109
Benthic Invertebrate Taxa		
Caenis (S)	**0.808**	0.065
Hexagenia limbata (S)	**0.794**	-0.350
Nanocladius (T)	**0.743**	-0.218
Chironomus (S)	**[illegible]734**	-0.204
Conchapelopia (T)	**0.688**	0.050
Cladotanytarsus (S)	**0.685**	-0.132
Dicrotendipes (S)	**0.664**	0.200
Psectrocladius (T)	**0.657**	0.265
Phylocentropus	**0.656**	-0.173
Stempellinella (S)	**0.642**	-0.365
Oecetis	**0.616**	0.053
Valvata tricarinata	**0.607**	0.381
Cricotopus (T)	**0.599**	**0.576**
Dubiraphia	**0.597**	-0.272
Zavreliella (S)	**-0.563**	0.464
Tanytarsus (S)	**0.554**	-0.201
Labrundinia (T)	**0.545**	0.359
Limnodrilus hoffmeisteri (T)	**-0.540**	0.191
Limnodrilus claparedianus (T)	**-0.524**	-0.123
Oromosia (?)(T)	**-0.520**	0.336
Acarina	**0.502**	0.083
Pisidium	**0.497**	-0.249
Nematoda	**-0.491**	-0.404
Pagastiella ostansa (S)	**0.489**	0.161
Ilyodrilus templetoni	**-0.486**	-0.306
Gyraulus parvus	0.192	**0.843**
Caecidotea (S)	-0.250	**0.626**
Hyalella azteca (S)	0.080	**0.614**
Physella gyrina	0.313	**0.567**
Hydra	0.166	**0.517**
Enchytraeidae	-0.401	**0.510**
Ablabesmyia (T)	0.028	**0.497**

Sediment Quality Triad

The biological data set was summarized as Dimensions 1 and 2 generated by NMDS. Total abundance and richness were also included in the triad analysis. Only PC1 was used to represent the chemistry data set, because the four metals of greatest concern (i.e., arsenic, cobalt, copper, and nickel) had high loadings on this component and PC1 explained most of the variance in the chemistry data set (Table 2.3-17). As in the case of the lake data set, silver was not included in the chemistry PCA, but was strongly correlated with PC1. The first two PCs were used to represent the toxicity data set (Table 2.3-18), because they both accounted for large proportions of the overall variance (Table 2.3-17). The final correlation analysis was run after deleting the two deep sites (MR-10 and MR-12) to remove the additional variation contributed by the depth-effect described earlier.

Table 2.3-17
Summary of the Sediment Chemistry and Toxicity PCAs,
River Habitat, Moira River System, Spring 1999

Data Set and Variable	PC1	PC2
Sediment Chemistry (component loadings)		
Nickel	0.986	0.126
Copper	0.963	-0.089
Cobalt	0.948	0.007
Arsenic	0.789	0.291
Lead	0.293	-0.940
Silver	(0.769)[a]	(0.382)[a]
Eigenvalue	3.505	0.991
Variance Explained (%)	70.1	19.8
Sediment Toxicity (component loadings)		
Hyalella azteca survival	0.869	-0.162
Hyalella azteca weight	0.702	-0.599
Chironomus riparius survival	0.283	0.891
Chironomus riparius weight	0.788	0.392
Eigenvalue	1.950	1.333
Variance Explained (%)	48.7	33.3

[a] Pearson correlation between silver concentrations and PC scores; silver was not included in the PCA due to missing data.

Table 2.3-18
Sediment Toxicity Data Set, River Habitat, Moira River System, Spring 1999

Site	*H. azteca* Survival (% control)	*H. azteca* Weight (% control)	*C. riparius* Survival (% control)	*C. riparius* Weight (% control)
BR-1	49	117	35	91
SKR-1	66	55	109	145
SR-1	92	104	93	86
SR-2	94	101	91	103
SR-3	92	94	82	97
MR-1	106	107	93	120
MR-3	89	112	105	135
MR-5	87	119	112	129
MR-8	11	45	95	39
MR-12	98	97	80	101
MR-13	98	83	68	79
MR-14	69	65	95	122
MR-15	86	87	86	96

The toxicity test results did not show a consistent relationship between effects on growth or survival and metal concentrations. For example, *Hyalella* growth and survival were substantially lower than controls in the Skootamatta River reference sample (SKR-1), the Moira River below Young's Creek sample (MR-8) with high metal concentrations and the Moira River at Latta sample (MR-14) with low metal concentrations. The Black River reference sample (BR-1) produced lower survival in *Chironomus riparius*, yet the Moira River below Young's Creek (MR-8) sample did not differ from controls. The only indication of any possible relationship between metal concentrations and toxicity test results was for the Moira River below Young's Creek sample (MR-8), where three of the four measures were lower than the control.

There were no significant correlations among the SQT components for the river data set (Table 2.3-19). In light of the high variability among reference sites and the general lack of statistically significant trends in the benthos with sediment metal concentrations in the univariate analysis, this result is not surprising. The absence of adverse effects at river sites is also consistent with the generally low bioavailability of sediment-bound metals in the Moira River system (Section 2.2). Metals released from the Deloro Mine Site are primarily in the more unavailable sediment fractions, with the exception of nickel and lead.

Table 2.3-19
Spearman Rank Correlations Among SQT Components, River Habitat, Moira River System, Spring 1999
(n=17, except for correlations with toxicity variables, where n=13; No significant correlations)

Data Set	Chemistry PC1	Toxicity PC1	Toxicity PC2	Benthos Abundance	Benthos Richness	Benthos Dim. 1	Benthos Dim. 2
Chemistry PC1	1	-	-	-	-	-	-
Toxicity PC1	-0.140	1	-	-	-	-	-
Toxicity PC2	0.063	0.112	1	-	-	-	-
Benthos – Abundance	0.079	-0.098	0.140	1	-	-	-
Benthos – Richness	0.326	-0.315	0.263	0.251	1	-	-
Benthos – Dimension 1	0.493	-0.413	0.329	0.186	0.476	1	-
Benthos – Dimension 2	-0.011	-0.545	-0.105	-0.307	0.064	-0.243	1

The only previous benthic survey in the Moira River system was carried out in 1969 (Owen and Galloway 1969). The authors reported adverse effects on the benthos of erosional habitats within a <10 km reach below the Deloro Mine Site. These effects consisted of reductions in the diversity and abundance of the bottom fauna and were attributed to arsenic toxicity. Concentrations of the metals of concern have declined substantially in river water since the 1960s, to levels that are below the PWQO in three seasons in a typical year, with the exception of cobalt, which usually exceeds the objective year-round (Section 2.1). Therefore, the lack of effects on depositional benthos in the Moira River in 1999 is consistent with the declining trends over time in both waterborne and sediment-bound metals in the upper Moira River.

2.3.2.3 General Summary

Lake Benthic Invertebrate Communities

Analysis of the lake benthos data detected some trends in benthic community structure that were consistent with the effects of elevated metal concentrations. However, despite the trends apparent upon visual examination of the data, statistical tests rarely detected significant differences between each of the exposed lakes (Moira and Stoco) and both reference lakes (Consecon and Round). This was largely the function of low statistical power in the pair-wise tests.

Total abundance was not affected by elevated metal concentrations and there were no readily apparent differences in benthic community composition between the reference lakes and the exposed lakes. In contrast, the richness data suggested a slight effect in Moira Lake and potentially in Bend Bay. The maximum richness in Moira Lake and richness at the single site sampled in Bend Bay were only slightly greater than the minimum value in the reference lakes, and total richness was significantly lower in Moira Lake relative to Consecon Lake. However, the pattern in richness within Moira Lake did not correspond with metal concentrations in the sediments.

Examination of the abundances of individual taxa and major invertebrate groups also suggested subtle effects of sediment metal concentrations, but low statistical power limited the ability to detect significant differences. For example, Oligochaete numbers were generally higher in the exposed lakes and were particularly high in Bend Bay, but there was no overall significant difference among lakes. A significant difference was found in total chironomid abundance between Consecon Lake and Moira Lake (with the lowest and highest metal concentrations, respectively), but not in any of the other comparisons. Additionally, differences among lakes in the percentages of major chironomid groups (which differ in metal sensitivity) were also consistent with metal concentrations in the sediments.

The strongest indication of metal-related effects on the benthic community was obtained by grouping taxa with known metal-sensitivity into sensitive and tolerant categories. The combined abundance and percentage of metal-sensitive invertebrates was significantly lower in Moira and Stoco lakes relative to both reference lakes. The trends for metal-tolerant taxa were less pronounced, largely because Consecon Lake communities included a moderate proportion of tolerant taxa.

Ordination of the lake benthos data showed separation of Consecon Lake communities from those of other lakes, but Round Lake sites were widely separated from each another. This analysis detected a gradual shift in community structure with increasing metal concentrations, although two of the three Round Lake sites detracted from this trend. Based on correlations of abundances of individual taxa with ordination axes, the change in community structure along the metal gradient appeared consistent with the metal sensitivity of common invertebrates in the lake communities.

Sediment Quality Triad analysis detected a significant correlation between benthic community structure and sediment chemistry. No significant correlations were found with sediment toxicity, as was expected, because lake sediments were not toxic to *Hyalella azteca* or *Chironomus riparius* in the laboratory.

The lack of any major effects on species composition or abundance may be related to the relative bioavailability of the metals in Moira Lake and Stoco Lake. Sequential extraction of the upper 0-5 cm of sediment cores from the lakes showed that the majority of metals are in the more unavailable forms (such as iron and manganese oxides and metal sulphides).

River Benthic Invertebrate Communities

Analysis of the data generated by the river benthic survey did not provide an indication of effects from metals of concern originating at the former Deloro Mine Site, with the exception of the site located in Young's Creek which appeared severely impacted. Variation in total invertebrate abundance was relatively large within the Moira River and was related to habitat attributes rather than sediment metal concentrations. The spatial pattern in richness generally reflected that in total abundance, with the exception that richness increased with distance downstream in the upper Moira River. As a result, there was a significant positive relationship between sediment metal concentrations and richness, which cannot be considered as evidence of a metal-related effect. A detailed study of sediment chemistry completed during this survey revealed that the metals of concern were largely in the more unavailable forms, such as the residual, oxides or organic/sulphide fractions.

Examination of a large number of biological variables also did not provide an indication of metal-related effects downstream from the former Deloro Mine Site. Occasional significant relationships were found between biological variables and sediment metal concentrations, largely in abundances of minor taxa. A number of these were also inconsistent with known metal sensitivity of the taxon involved. The combined abundance and percentages of metal-sensitive and metal-tolerant invertebrates was not significantly related to sediment metal concentrations or habitat variables. The lower Moira/Salmon River comparisons yielded non-significant results for all but two of the 25 biological variables tested.

Ordination of the river benthos data implied the potential for a slight shift in benthic community structure in response to sediment metal concentrations, but the type of community shift did not lend itself to a simple interpretation based on metal-sensitivity of individual benthic taxa. There was no consistency with regard to metal-sensitivity in the groups of taxa that were significantly correlated with either biological ordination axis. Similarly, there were no significant correlations between environmental variables and ordination axes.

The laboratory toxicity tests did not reveal a consistent relationship between effects on growth or survival of *Hyalella azteca* or *Chironomus riparius* and metal concentrations in sediments.

Sediment Quality Triad analysis did not find significant correlations between benthic community structure, sediment chemistry or sediment toxicity. The apparent lack of effects on the benthic community of the upper Moira River below the former Deloro Mine Site was most likely a function of low bioavailability of sediment-bound metals. The lack of effects in the lower Moira River were consistent with generally low metal concentrations resulting from settling of metal-laden sediments in Moira and Stoco Lakes.

The lack of any significant effects on the benthic invertebrate community in the Moira River may be because the metals are not available for uptake by benthic organisms. Sequential extraction of the upper 0-5 cm of sediment cores from river depositional areas showed that most of the metals are in the more unavailable fractions (such as the residual, iron and manganese oxide, or organic/sulphide fractions).

References

Bedard, D., A. Hayton and D. Persaud. 1995. Ontario Ministry of the Environment Laboratory Sediment Biological Testing Protocol. Resources Branch, Ontario Ministry of the Environment, Queen's Printer for Ontario. ISBN 0-7729-9924-4.

Beltman, D.J., W.H. Clements, J. Lipton and D. Cacela. 1999. Benthic invertebrate metals exposure, accumulation, and community-level effects downstream from a hard-rock mine site. Environmental Toxicology and Chemistry, 18(2): 299-307.

Canfield, T.J., N.E. Kemble, W.G. Brumbaugh, F.J. Dwyer, C.G. Ingersoll and J.F. Fairchild. 1994. Use of benthic invertebrate community structure and the sediment quality triad to evaluate metal-contaminated sediment in the upper Clark Fork River, Montana. Environmental Toxicology and Chemistry, 13(12): 1999-2012.

Chapman, P.M. 1990. The sediment quality triad approach to determining pollution-induced degradation. Sci. Total Envir. 97/98: 815-825.

Chapman, P.M., B.A.. Power, R.N. Dexter and H.B. Anderson. 1991. Evaluation of effects associated with an oil platform, using the sediment quality triad. Environ. Toxicol. Chem. 10: 407-424.

Chapman, P.M., R.N. Dexter and E.R. Long. 1987. Synoptic measures of sediment contamination, toxicity and infaunal community composition (the Sediment Quality Triad) in San Francisco Bay. Mar. Ecol. Prog. Ser. 37: 75-96.

Clarke. K.R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology. 18: 117-143.

Clements, W.H. 1991. Community responses of stream organisms to heavy metals: a review of observational and experimental approaches. In Newman, M.C. and A.W. McIntosh. 1991. Metal Ecotoxicology, concepts and applications. Lewis Publishers, Chelsea Michigan.

Environment Canada. 1997a. Biological test method: test for survival and growth in sediment using the freshwater amphipod *Hyalella azteca.* Environment Canada, Conservation and Protection, Ottawa, Ontario. Report EPS 1/RM/33.

Environment Canada. 1997b. Biological test method: test for survival and growth in sediment using the larvae of freshwater midges (*Chironomus tentans* or *Chironomus riparius*). Environment Canada, Conservation and Protection, Ottawa, Ontario. Report EPS 1/RM/32.

Green, R.H., J.M. Boyd and J.S. Macdonald. 1993. Relating sets of variables in environmental studies: the sediment quality triad as a paradigm. Environmentrics, 4(4): 439-457.

Klemm, D.J., P.A. Lewis, R. Fulk and J.M. Lazorchak. 1990. Macroinvertebrate field and laboratory methods for evaluating the biological integrity of surface waters. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Monitoring Systems Laboratory – Cincinnati, Ohio. EPA/600/4-90/030.

Long, E.T., and P.M. Chapman. 1985. A sediment quality triad: measures of sediment contamination, toxicity and infaunal composition in Puget Sound. Marine Pollution Bulletin. 16: 405-415.

Mance, G. 1987. Pollution threat of heavy metals in aquatic environments. Elsevier, New York.

Mori, C., A. Orsini and C. Migon. 1999. The impact of arsenic and antimony contamination on the benthic invertebrates in a minor Corsican river. Hydrobiologia, 392(1): 73-80.

Owen. G.E., and D.L. Galloway. 1969. Biological survey of the Moira River, 1969. Ontario Ministry of the Environment.

Paine, M. 1998. Volume II: CANMET/MMSL – INTEMIN Manual on statistical analysis of environmental data. Prepared by Paine, Ledge and Associates.

Poulton, B.C., D.P. Monda, D.P. Woodward, M.L Wildhaber and W.G. Brumbaugh. 1995. Relations between benthic community structure and metals concentrations in aquatic macroinvertebrates: Clark Fork River, Montana. Journal of Freshwater Ecology, 19(3): 277-293.

Winner, R.W., M.W. Boesel and P. Farrell. 1980. Insect community structure as an index of heavy-metal pollution in lotic systems. Can. J. Fish. Aquat. Sci. 37: 647-655.

2.4 Metal Concentrations in the Two Fish Sentinel Species in the Moira River System

2.4.1 Methods

The original study design included analysis of white sucker liver and benthic invertebrate samples for metals. The spring 1999 sediment and benthic invertebrate sampling program showed that there were insufficient numbers of benthic invertebrates at the reference and exposed sites to allow analysis of metals in invertebrate tissues. Furthermore, Golder had expressed some concerns regarding the reliance on white sucker liver samples to represent metals uptake. Golder also suggested substituting analysis of longnose dace for analysis of benthic invertebrates. Golder was asked to prepare recommendations regarding alternatives for tissue analysis. These recommendations were presented to the Steering Committee and approved. The methods outlined below represent the approved changes to the study design for examination of metal concentrations in biota from the Moira River system.

There were two main objectives for the analysis of metals, arsenic and radionuclides in fish tissue:

1. To obtain levels in fish flesh for use in the human health risk assessment; and
2. To obtain exposure information for the sentinel species (i.e., to assess the degree of metals uptake in white sucker and longnose dace.)

The first objective was met by the sport fish sampling conducted by the MOE. Sport fish monitoring data are summarized in Chapter 3 as part of the supporting information for the PQRA. The second objective was met by using the study design outlined below. The detailed rationale, study design and sampling protocols are in Appendix IV.

The main objective for the analysis of metals in white sucker and longnose dace was to obtain exposure information (i.e., to assess the degree of metals uptake). This was necessary in order to establish that these two species did, in fact, have elevated metal concentrations in the exposed study sites compared to the reference sites. This was a required first step in the evaluation of potential links between metal exposure in the sentinel species and effects.

Although logical, the application of a tissue residue approach to exposure characterization is complex. First, there should be an understanding of the mechanisms or modes of action for the chemical of concern, such that appropriate tissues are sampled. For example, in order to define robust residue-based effects relationships for cationic metals, it may be necessary to focus upon tissues or sites of action (e.g., gill) that are not routinely sampled (Wood *et al.* 1997). Alternatively, even though such relationships may not allow determination of mechanistic processes, it might be possible to derive useful correlations between some internal chemical residue for metals and observed effects (Wood *et al.* 1997). Therefore, the challenge for the Moira River Study was to be sure that the appropriate tissue was selected in order to allow a reasonably confident analysis of relationships between tissue residue levels and observed effects.

Selection of Appropriate Tissues for Analysis

Appropriate tissues vary with the metal. For example, the appropriate tissue for arsenic may be different than that for copper or zinc. Existing water quality data for the Moira River system indicated that the primary metal of concern was arsenic.

The majority of studies linking tissue level with effects use whole body analysis of arsenic (Jarvinen and Ankely 1999). For example, McGeachy and Dixon (1990, 1992) reported whole body levels of sodium arsenate along with survival or growth endpoints for rainbow trout. Cockell and Hilton (1988) reported “Carcass” residues of arsenic trioxide and survival and growth endpoints. Sorensen (1976) reported whole body, liver, gut, and muscle residues of sodium arsenate (As^{+5}) in green sunfish along with survival endpoints. Gilderhus (1966) reported whole body levels of sodium arsenite (As^{+3}) in bluegill, along with survival and growth endpoints.

The information for the other metals of concern confirmed that appropriate tissues varied with the particular metal. Copper accumulates to a greater extent in liver than in most other tissues, and several authors have made linkages between liver residues and effects on growth and survival (Jarvinen and Ankley 1999). However, linkages between whole body residues of copper and effects are also available in the literature (Jarvinen and Ankely 1999). Nickel appears to accumulate primarily in gill tissue and in kidney, although liver, muscle and whole body residues are also significant (Jarvinen and Ankley 1999). The only linkage between nickel tissue residue and effect is for survival. The only data on the linkage between silver tissue residues and effects are for whole body, gill and "internal organs" data (Coleman and Cearley 1974). Lead appears to accumulate preferentially in kidney and spleen, although liver and gill tissues also can contain significant amounts (Jarvinen and Ankley 1999). Linkages between tissue residues and effects have been made for liver, kidney, gill, spleen, and whole body data. There are no data linking tissue residues of cobalt and effects.

On the basis of the existing literature linking tissue residues with effects, whole body analyses were conducted in both white sucker and longnose dace. This allowed for comparison of results with a longer list of literature values and a more comprehensive database linking residues with effects than for liver analysis only. White sucker were collected from lakes and larger sections of the Moira River including:

- Moira River at Bend Bay (MR-11);
- Moira River downstream of Stoco Lake (MR-17, MR-14, MR-15 at Thomasburg, Latta and Highway 37, respectively);
- Moira Lake (ML);
- Stoco Lake (SL);
- Consecon Lake (CL); and
- Round Lake (RL).

Longnose dace were collected from the following river sites:

- A reference site upstream of the Malone bridge (F-1 near MR-1);
- A reference site at the Malone bridge (F-2 near MR-3); and
- An exposed site near the Old Marmora Road (F-3 near MR-7).

These sites are different from those specified in the original study design (Appendix IV) because the actual longnose dace sample locations changed once the field crew was in the field. The collection of these fish species at these locations corresponded to the requirements of the fish population survey, which was conducted at the same time.

Ten specimens of white sucker and 10 composite samples of longnose dace were taken and analyzed for metals (including uranium). The sample size of 10 has been shown to be adequate to distinguish “exposed” from reference sites in other studies (radionuclides and metals) (Swanson 1985, U.S. EPA 1993). This sample size will distinguish differences of approximately 30-35% for uranium-series radionuclides (Swanson 1985) and approximately 10-20% for metals (assuming a mean: variance ratio of 0.5-1.0) (U.S. EPA 1993).

The 10 samples of white sucker were individual fish (gutted). Each of the 10 samples of longnose dace consisted of a minimum of 5 individuals (preferably 10 if obtainable).

Two size-classes of white sucker were selected for analysis (5 specimens from each size class). The first size-class represented the younger, faster-growing fish (with potentially greater metal uptake). The first size-class was 10-30 cm (fork length). The second size class was > 30 cm.

A detailed Technical Procedure for sampling fish for metals and radionuclides is included in Appendix IV. The Technical Procedure for producing homogenates of the fish samples is also included in Appendix IV.

Metal concentrations were compared among sampling sites using one-way ANOVA, followed by Tukey’s tests. The metals examined for differences with site were: arsenic, cobalt, copper, lead, nickel, silver and uranium.

Bioaccumulation factors (BAFs) were calculated for water-to-fish and sediment-to-fish metal transfer. The average water concentration in 1999 for each fish sampling station was used for the water-to-fish BAFs. The sediment metal concentration from sediment grab samples in 1999 was used for the sediment-to-fish BAFs. In the case of the lakes, the data from all water quality and sediment quality stations in each lake were combined, since fish are mobile and will experience lake-wide water and sediment quality.

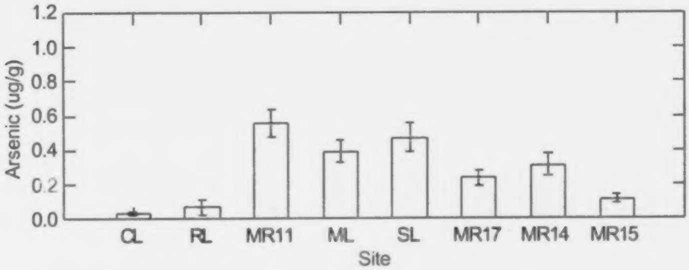
2.4.2 Results and Discussion

White Sucker

Arsenic was the most elevated metal in whole body white sucker samples compared to reference concentrations. Arsenic concentrations in whole body white sucker samples were significantly higher ($P < 0.05$) than reference locations at Bend Bay (MR-11), Moira Lake (ML), Stoco Lake

(SL) and the Moira River at Latta (MR-14) (Figure 2.4-1). The highest overall concentrations were in Bend Bay samples, ranging from 0.26 to 1.09 µg/g. In contrast, reference fish arsenic concentrations ranged from 0.01 to 0.05 µg/g.

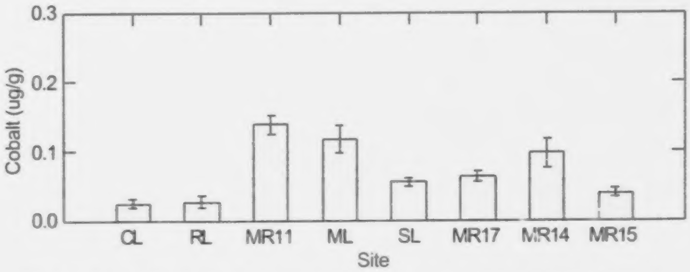
Figure 2.4-1
Average (with Standard Error) of Arsenic Concentration in White Sucker Tissue Samples Taken at Each Location



Fish collected from Moira Lake, (ML), Consecon Lake (CL) and Round Lake (RL) were collected from several locations within the lake.

Cobalt concentrations in whole body white sucker samples were significantly higher ($P < 0.05$) at Bend Bay (MR-11), Moira Lake (ML) and Latta (MR-14) (Figure 2.4-2). The highest concentrations were at Bend Bay, ranging from 0.04 to 0.2 µg/g. Reference concentrations ranged from 0.01 to 0.07 µg/g.

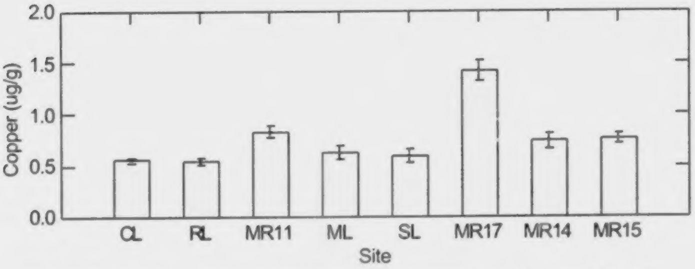
Figure 2.4-2
Average (with Standard Error) of Cobalt Concentration in White Sucker Tissue Samples Taken at Each Location



Fish collected from Moira Lake, (ML), Consecon Lake (CL) and Round Lake (RL) were collected from several locations within the lake.

Copper concentrations in whole body white sucker samples were significantly higher ($P < 0.05$) at Bend Bay (MR-11) and Thomasburg (MR-17) (Figure 2.4-3). Bend Bay concentrations ranged from 0.57 to 1.1 µg/g. The highest overall concentrations were in fish from the Thomasburg site, ranging from 0.98 to 1.9 µg/g. Reference concentrations ranged from 0.41 to 0.77 µg/g.

Figure 2.4-3
Average (with Standard Error) of Copper Concentration in White Sucker Tissue Samples Taken at Each Location

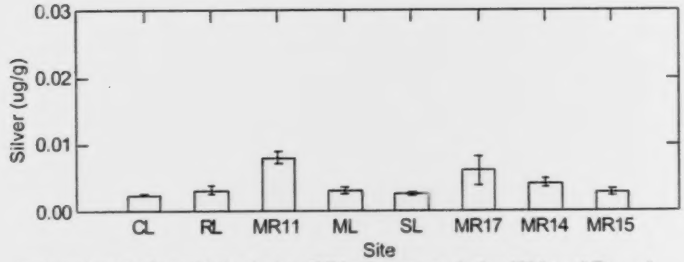


Fish collected from Moira Lake, (ML), Consecon Lake (CL) and Round Lake (RL) were collected from several locations within the lake.

Lead and nickel concentrations in whole body white sucker samples were not elevated above reference concentrations at any of the Moira River system sites (Appendix IV).

Silver concentrations in whole body white sucker samples were relatively uniform across all reference and Moira River system sites, with the exception of Bend Bay (Figure 2.4-4). Concentrations at Bend Bay ranged from 0.004 to 0.01 µg/g. Concentrations at all other sites ranged from 0.001 to 0.005 µg/g.

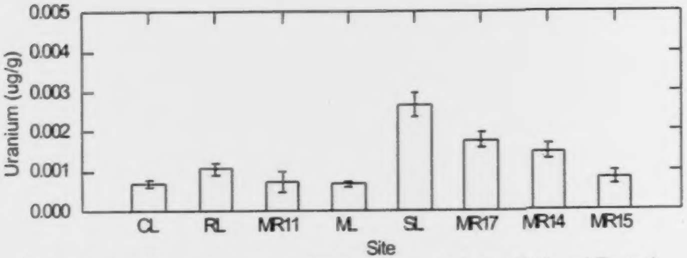
Figure 2.4-4
Average (with Standard Error) of Silver Concentration in White Sucker Tissue Samples Taken at Each Location



Fish collected from Moira Lake, (ML), Consecon Lake (CL) and Round Lake (RL) were collected from several locations within the lake.

Uranium concentrations in whole body white sucker samples were significantly higher ($P < 0.05$) in Stoco Lake than at reference locations (Figure 2.4-5). The significant difference was produced by only a small actual difference. Concentrations in Stoco Lake white sucker ranged from 0.001 to 0.004 µg/g whereas at the other sites, concentrations ranged from 0.0005 to 0.003 µg/g.

Figure 2.4-5
Average (with Standard Error) of Uranium Concentration in White Sucker Tissue Samples Taken at Each Location



Fish collected from Moira Lake, (ML), Consecon Lake (CL) and Round Lake (RL) were collected from several locations within the lake.

There was no relationship between fish size and metal concentrations in whole body samples. Smaller white sucker (<30 cm length) did not have significantly lower or higher metal concentrations than larger white sucker (> 30 cm length) (Appendix IV).

There are few previous data on metal concentrations in white sucker from the Moira River system. Azcue and Dixon (1994) reported that arsenic concentrations in 4 composite samples of white sucker from Moira Lake ranged from 0.099 to 0.166 µg/g. Moira Lake white sucker samples in this study ranged from 0.20 to 0.76 µg/g.

Arsenic concentrations in whole white sucker from the Moira River system are similar to concentrations found in northern Saskatchewan where uranium mining activity has resulted in elevated arsenic concentrations because arsenic occurs in the uranium ore (Table 2.4-1). Collins Bay in Wollaston Lake, Saskatchewan, is the site of an open-pit uranium mine that extended out into the bay. Arsenic concentrations in lake whitefish from this location averaged 0.22-0.33 µg/g. Arsenic concentrations in whole white sucker from Bend Bay ranged from 0.26 to 1.09 µg/g. Thor Lake, N.W.T. and South McMahon Lake were the sites of baseline studies prior to mining development. Arsenic concentrations in lake whitefish and white sucker from these locations are very similar to the reference concentrations recorded in this study (Table 2.4-1).

Table 2.4-1
Comparison of Arsenic and Metal Concentrations Measured in Fish Tissue at Some Canadian Sites

Location	Fish Species	Analyte	Tissue Analyzed	Tissue Residue (µg/g)	Reference
Ten lakes in the Sudbury region	Walleye	Copper	Muscle	0.6-0.7	Bradley and Morris 1986
			Liver	8.7-75.3	
	Smallmouth bass	Copper	Muscle	1.0	
			Liver	4.8-8.5	
	Northern pike	Copper	Muscle	0.6-0.8	
			Liver	21.8-66.2	
	White sucker	Copper	Muscle	0.8-1.1	
			Liver	36.1-102	
	Lake Whitefish	Copper	Muscle	0.6-0.7	
			Liver	25.7-88.2	
	Lake trout	Copper	Muscle	1.0-1.1	
			Liver	47.8-166	
Baie du Doré	Alewife, Brown bullhead, carp, freshwater drum, gizzard shad, golden shiner, lake whitefish, largemouth bass, longnose sucker, pumpinseed, rainbow smelt, rock bass, white sucker, yellow perch	Copper	Muscle	0.12-1.14	Brown and Chow 1977
			Liver	0.62-21.84	
			Kidney	0.27-20.17	
		Lead	Muscle	0.09-0.36	
			Liver	0.05-0.57	
			Kidney	0.16-6.76	
Toronto Harbour	As above	Copper	Muscle	0.54-4.01	Brown and Chow 1977
			Liver	1.48-68.40	
			Kidney	1.88-13.58	
		Lead	Muscle	0.13-2.35	
			Liver	0.22-2.19	
			Kidney	0.66-61.40	

Location	Fish Species	Analyte	Tissue Analyzed	Tissue Residue (µg/g)	Reference
Wollaston Lake, Saskatchewan (Collins Bay)	Lake Whitefish	Arsenic	Muscle	0.33 ± 0.33	Swanson 1989
			Bone	0.22 ± 0.10	
		Copper	Muscle	2.8 ± 3.2	
			Bone	1.0 ± 0.74	
		Nickel	Muscle	0.39 ± 0.06	
			Bone	0.94 ± 1.1	
		Uranium	Muscle	<0.001-0.005	
			Bone	0.002-0.04	
Wollaston Lake, Saskatchewan (Hidden Bay)	Lake Whitefish	Copper	Muscle	0.21 ± 0.06	Swanson 1989
			Bone	0.41 ± 0.01	
		Nickel	Muscle	1.26 ± 2.03	
			Bone	0.58 ± 0.54	
		Uranium	Muscle	<0.001-0.06	
			Bone	0.007-0.5	
Thor Lake, NWT	Lake Whitefish	Arsenic	Muscle	0.01 ± 0.009	Swanson 1989
			Bone	0.05 ± 0.03	
		Copper	Muscle	<0.02	
			Bone	0.16 ± 0.02	
		Nickel	Muscle	<0.02	
			Bone	0.16 ± 0.02	
		Uranium	Muscle	0.002 ± 0.0001	
			Bone	0.02 ± 0.001	
Beaverlodge Lake, Saskatchewan	White Sucker	Uranium	Skin	0.50 ± 0.08	Swanson 1985
			Muscle	0.56 ± 0.12	
			Bone	0.46 ± 0.05	
			Stomach	3.54 ± 0.94	
			Liver	0.16 ± 0.06	
			Gonad	0.009 ± 0.002	
Lake Huron	Bloater Chubs, Burbot	Lead	Whole Body	0.05-0.08	Hodson *et al.* 1984
Lake Superior	Bloater Chubs, Burbot, Lake Trout	Lead	Whole Body	0.04-0.06	Hodson *et al.* 1984
Lake Ontario	Lake Trout, Rainbow Trout, Coho Salmon, Yellow Perch, Rainbow Smelt	Lead	Whole Body	<0.1-0.4	Hodson *et al.* 1984
Lake Erie	Northern Pike, Walleye, Yellow Perch, Rainbow Smelt	Lead	Whole Body	0.1-0.20	Hodson *et al.* 1984
South McMahon Lake, Saskatchewan	White Sucker	Arsenic	Muscle	0.02 ± 0.00004	Swanson 1989
			Bone	0.004 ± 0.0002	
		Copper	Muscle	0.29 ± 0.03	
			Bone	1.03 ± .020	
		Nickel	Muscle	0.05 ± 0.018	
			Bone	0.20 ± 0.13	
		Uranium	Muscle	<0.01	
			Bone	<0.01	

Copper concentrations in whole white sucker from the Moira River system are somewhat lower that those reported from ten lakes in the Sudbury region, and much lower than concentrations measured in several fish species from Baie du Doré and Toronto Harbour (Table 2.4-1). The copper concentrations found in this study appear to be most similar to those measured in fish from Wollaston Lake and South McMahon Lake, Saskatchewan and Thor Lake, N.W.T. (Table 2.4-1).

Lead concentrations in white sucker in this study are much lower than concentrations measured in several fish species from Baie du Doré and Toronto Harbour (Table 2.4-1). Concentrations were similar to those found in several fish species in the Great Lakes (Table 2.4-1). Lead does not usually accumulate in significant quantities in edible portions of fish, except in cases of extreme pollution (Moore and Ramamoorthy 1984).

Nickel concentrations measured in white sucker in this study are much lower than in lake whitefish from Collins Bay of Wollaston Lake, Saskatchewan (Table 2.4-1). Nickel is a significant component of the uranium ore mined at Collins Bay. The nickel concentrations found in this study are similar to baseline concentrations measured in South McMahon Lake, Saskatchewan and Thor Lake, N.W.T. (Table 2.4-1).

Most literature on cobalt uptake in fish is for the marine environment (e.g., Eisler and LaRoche 1972, Pentreath 1973, Udea and Nakahara 1983), describes the results of whole–lake experiments tracing cobalt-60 in food chains (Klaverkamp *et al.* 1983), or describes uptake in laboratory studies (Feldt and Melzer 1978, Baudin *et al.* 1990). There are few studies of cobalt uptake in wild fish. The average cobalt concentrations measured in carp (*Cyprinus carpio*) from the Danube River and Danube Canal was 0.18 μg/g (± 0.08) (Rehwoldt *et al.* 1976). This mean falls within the range of cobalt concentrations measured in white suckers from Bend Bay in this study (0.04-0.2 μg/g). The Danube River receives significant effluent input from a wide variety of industries. The Moira River has received input from the Deloro Mine Site for decades. Despite this, cobalt concentrations in fish in these two locations are relatively low.

Uranium concentrations in whole white sucker from the Moira Lake system were similar to reference (unaffected by mining) concentrations measured in northern Saskatchewan and Thor Lake, N.W.T. (Table 2.4-1). They were much lower than concentrations reported in white sucker in Beaverlodge Lake, Saskatchewan (Table 2.4-1). Beaverlodge Lake received tailings effluent from the Eldorado Nuclear uranium mine for almost 30 years.

Bioaccumulation factors (BAFs) for uptake in whole body white sucker from water were highest for copper (averaging 937) and lowest for uranium (averaging 5.6) (Appendix IV). Arsenic BAFs were relatively low (averaging 22).

Bioaccumulation from sediment was also highest for copper (averaging 0.01) and lowest for lead and uranium (averaging 0.0005) (Appendix IV). Sediment BAFs were an order of magnitude higher at Bend Bay for arsenic, cobalt, nickel and silver than at any of the other sites.

Bioaccumulation factors from water-to-sucker did not vary substantially with site. There were no consistent trends (such as higher BAFs at the exposed sites versus the reference sites).

Sediment-to-fish transfer was higher at the Bend Bay site for some of the metals (arsenic, cobalt, nickel and silver). There was a similar range of sediment-based BAFs at all other sample sites.

Longnose Dace

Arsenic, silver and nickel were the only metals that had significantly higher concentrations ($P < 0.05$) in longnose dace at the site downstream of the Deloro Mine Site compared to the two upstream sites (Figures 2.4-6 to 2.4-8). Arsenic was the most elevated relative to the reference data. Arsenic ranged from 0.87 to 1.9 µg/g in the downstream dace samples, whereas the upstream reference dace concentrations were from 0.05 to 0.14 µg/g. Nickel concentrations ranged from 0.28 to 0.64 µg/g at the downstream site. Upstream nickel concentrations ranged from 0.16 to 0.48 µg/g. Downstream silver concentrations were from 0.093 to 0.07 µg/g whereas reference concentrations were from 0.005 to 0.01 µg/g.

Figure 2.4-6
Average (with Standard Error) of Arsenic Concentration in Longnose Dace Tissue Samples Taken at Each Location

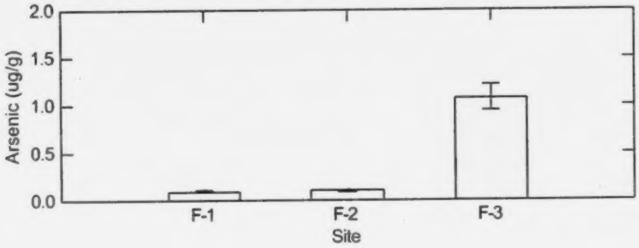


Figure 2.4-7
Average (with Standard Error) of Silver Concentration in Longnose Dace Tissue Samples Taken at Each Location

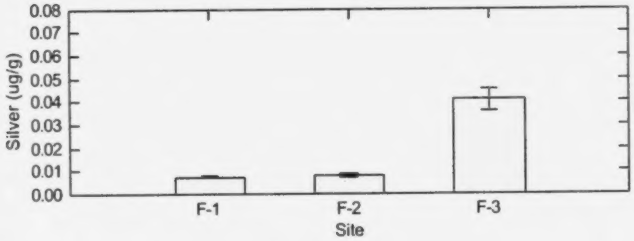
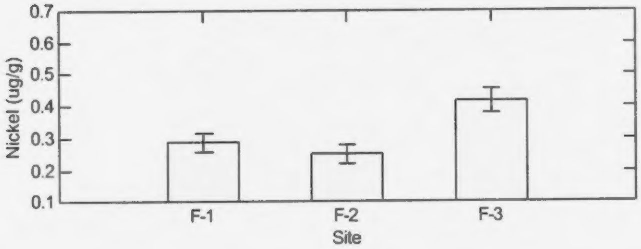


Figure 2.4-8
Average (with Standard Error) of Nickel Concentration in Longnose Dace Tissue Samples Taken at Each Location



Arsenic concentrations in longnose dace from the downstream site were about an order of magnitude higher than concentrations measured in rock bass, spottail shiner, bluntnose minnow, golden shiner and emerald shiner sampled from Moira Lake in 1991 (Azcue and Dixon 1994). The concentrations from the downstream site were similar to concentrations in creek chub from Moira Lake in 1991 (Azcue and Dixon 1994).

Since methods were very similar, the most likely explanation for the differences between the results of this study and the results reported by Azcue and Dixon is that there are marked differences among fish species in the rates of arsenic uptake and elimination (Foley *et al.* 1978). Azcue and Dixon observed inter-species differences, even among closely related species. For example, mean arsenic concentrations in spottail shiner, golden shiner and emerald shiner were 0.03 µg/g, 0.167 µg/g and 0.04 µg/g, respectively. Highest arsenic concentrations were found in creek chub (2.36 µg/g) and lowest concentrations were found in northern pike (0.025 µg/g). Azcue and Dixon did not find differences between benthic-feeding fish and pelagic feeders. They suggested that the absence of elevated arsenic concentrations in benthic feeders was related to the very low percentage of arsenic in the most biologically-available form (the exchangeable fraction) in Moira Lake sediments. Although this study did not compare benthic and pelagic fish, it also found that arsenic was primarily in the less biologically-available fractions.

Bioaccumulation factors for water-to-fish transfer of metals to longnose dace were highest for copper (averaging 1921) and lowest for lead (averaging 3). Arsenic and silver showed intermediate BAFs, averaging 70 and 92, respectively. Cobalt and nickel BAFs averaged 600 and 208, respectively. Uranium BAFs averaged 4.

Bioaccumulation factors for sediment-to-fish transfer of metals to longnose dace were highest for copper (averaging 0.03) and lowest for lead and uranium (averaging 0.0006 and 0.0009 respectively) (Appendix IV).

There was some variability in BAFs among the three sample sites; however, the exposed site (downstream of Deloro) did not consistently produce higher BAFs.

Comparison of BAFs in This Study with Other Data

The BAFs found in this study generally fall within ranges reported in other studies for arsenic, copper and uranium uptake in wild fish (Moore and Ramamoorthy 1984; Swanson 1985, 1989).

Long-term laboratory exposures to arsenic in the diet produced BAFs that were similar to those observed for sediment-to-fish in this study. For example, exposure of rainbow trout for 56 days to arsenic in the diet produced BAFs ranging from 0.004 to 0.02 (Cockell and Hilton 1988). The BAFs for sediment-to-fish in the Moira River system ranged from 0.0007 to 0.02.

The BAFs for cobalt in this study were greater than those reported by Harrison *et al* (1990) for fathead minnows and lake trout 63 days after cobalt was added to an experimental lake. The BAFs for fathead minnow and lake trout in were 190 and 58, respectively (Harrison *et al.* 1990). The BAFs for longnose dace in this study ranged from 33-967 (Appendix IV). The BAFs for white sucker in this study ranged from 40-120 (Appendix IV).

Long-term laboratory exposures to copper in the diet also produced somewhat similar BAFs to those observed for sediment-to-fish in this study. The BAFs for rainbow trout exposed to copper sulphate in the diet ranged from 0.005 to 0.5, depending upon tissue (Lanno *et al.* 1985). The BAFs for copper transfer from sediment-to-fish in the Moira River system ranged from 0.002 to 0.04.

The BAFs for nickel and silver from this study are higher than BAFs calculated from data presented in laboratory studies (data from comparable field studies could not be located). Laboratory exposures produced nickel BAFs for water-to-fish ranging from 0.8 to 4 for rainbow trout and 5 to 129 for carp (Calamari *et al.* 1982; Sreedevi *et al.* 1992). The nickel BAFs for in this study ranged from 61 to 208. Laboratory exposures produced silver BAFs for water-to-fish ranging from 10 to 17 in largemouth bass (Coleman and Cearley 1974). Silver BAFs in this study ranged from 12-202.

The BAFs for lead from this study are lower than BAFs calculated from laboratory studies. Laboratory exposure produced BAFs for water-to-fish ranging from 13-1083 for rainbow trout and 3 to 295 for brook trout (Holcombe *et al.* 1976; Hodson *et al.* 1978). The BAFs in this study ranged from 2 to 15.

While interesting in their own right, the main purpose of the whole body metal concentration data in this report is to confirm exposure in the sentinel fish specimens collected from the "exposed" sites. The data clearly show that that the fish collected for this study have been exposed to elevated metal concentrations.

Relationship Between Metal Concentrations in Fish and Effects

On the basis of the whole body concentrations observed in fish from the Moira River system, the literature indicates that effects would not be expected. Existing information compiled by Jarvinen and Ankley (1999) linking tissue residues and effects in laboratory exposures shows that effects occur at whole body concentrations that are considerably higher than observed in this study (Table 2.4-2). In contrast to the whole body concentrations in Table 2.4-2, the highest arsenic concentrations found in white sucker and longnose dace in this study were 0.26 to 1.09 µg/g and 0.87 to 1.9 µg/g, respectively. Concentrations of other metals in fish from this study were even lower than arsenic, with the exception of copper where the highest concentrations in white sucker were from 0.57 to 1.1 µg/g.

This study went beyond measurement of metal concentrations in fish to a study of fish health parameters in the two sentinel species (Section 2.5). The results of the fish health study confirmed the prediction that no effects would be found.

Summary

The measurement of metal concentrations in whole body fish samples confirmed the presence of elevated concentrations in fish downstream of the Deloro Mine Site. Thus, the white sucker and longnose dace studied for effects did, indeed, have greater exposure to the metals of concern than reference fish.

While elevated, metal concentrations in longnose sucker from the Moira River system were not as high as in fish from other mining areas, and were much lower than areas affected by a broad spectrum of contaminant sources (e.g., Toronto Harbour). The exception was arsenic concentrations, which were similar to concentrations found in fish near uranium mines.

Metal concentrations in longnose dace were higher than concentrations in some other small fish species from the Moira River sampled in 1991. These differences are likely due to differences among fish species in the rates of arsenic uptake and elimination.

Table 2.4-2
Whole Body Metal Concentrations and Effects in Various Fish Species
(Jarvinen and Ankley 1999)

Species	Life Stage	Metal	Test Conditions	Whole Body Residue	Effect
Rainbow Trout (*Oncorhynchus mykiss*)	Juvenile	Arsenic	Laboratory flow-through	11.2 to 17.9 µg/g	Reduced survival
Rainbow Trout (*Oncorhynchus mykiss*)	Juvenile	Arsenic	Laboratory flow-through	3.1 to 6.9 µg/g	Reduced growth
Rainbow Trout (*Oncorhynchus mykiss*)	Fingerling	Arsenic	Laboratory flow-through	3.0 to 13.5 µg/g	Reduced survival
Bluegill (*Lepomis macrochirus*)	Adult	Arsenic	Field: outdoor pools	11.7 µg/g	Reduced growth
Bluegill (*Lepomis macrochirus*)	Juvenile	Arsenic	Field: outdoor pools	2.24 to 11.7 µg/g	Reduced growth
Carp (*Cyprinus carpio*)	Larvae	Copper	Laboratory flow-through	11.1 to 11.7 µg/g	Reduced survival
Brook Trout (*Salvelinus fontinalis*)	Embryo	Lead	Laboratory flow-through	0.4 µg/g	Reduced hatchability
Brook Trout (*Salvelinus fontinalis*)	Embryo-juvenile	Lead	Laboratory flow-through	4.0 to 8.8 µg/g	Reduced growth
Largemouth Bass (*Micropterus salmoides*)	Young of the year	Silver	Laboratory static, aerated	0.003 µg/g (carcass without internal organs)	No effect on survival or growth
Bluegill (*Lepomis macrochirus*)	Young of the year	Silver	Laboratory static, aerated	0.06 µg/g	No effect on survival or growth

References

Azcue, J.M. and D.G. Dixon. 1994. Effects of past mining activities on the arsenic concentration in fish from Moira Lake, Ontario. J. Great Lakes Res. 20(4): 717-724.

Baudin, J.P., A.F. Fritsch and J. Georges. 1990. Influence of labelled food type on the accumulation and retention of ^{60}Co by a freshwater fish, *Cyprinus carpio* L. Water, Air and Soil Pollution. 51:261-270.

Bradley, R.W. and J.R. Morris. 1986. Heavy metals in fish from a series of metal-contaminated lakes near Sudbury, Ontario. Water, Air and Soil Pollution 27: 341-354.

Brown, J.R. and L.Y. Chow. 1977. Heavy metal concentrations in Ontario fish. Bull. Environ. Contam. Toxicol. 17(2): 190-195.

Calamari, D., G.F. Gaggino and G. Pacchetti. 1982. Toxicokinetics of low levels of Cd, Cr, Ni and their mixture in long-term treatment on *Salmo gairdneri* Richardson. Chemosphere 11:59-70.

Cockell, K.A. and J.W. Hilton. 1988. Preliminary investigations on the comparative chronic toxicity of four dietary arsenicals to juvenile rainbow trout. Aquat. Toxicol. 12: 73-82.

Coleman, R.L. and J.I. Cearley. 1974. Silver toxicity and accumulation in largemouth bass and bluegill. Bull. Environ. Contam. Toxicol. 12:53-61.

Eisler, R. and G. LaRoche. 1972. Elemental composition of the estuarine teleost *Fundulus heteroclitus* (L.). J. Exp. Mar. Biol. Ecol. 9:29-42.

Feldt, W. and M. Melzer. 1978. Konzentrationsfatoren der Elemente Kobalt, Mangan, Eisen, Zink und Silber für Fische. Arch. Fisch. Wiss. 29:105-112.

Foley, R.E., F.R. Spotila, J.P. Giesy and S.H. Wall. 1978. Arsenic concentrations in water and fish from Chautauqua Lake, New York. Environ. Biol. Fish. 3: 361-367.

Gilderhus, PA. 1966. Some effects of sublethal concentrations of sodium arsenite on bluegills and the aquatic environment. Trans. Am. Fish. Soc 95: 289-296.

Harrison, S.E., J.F. Klaverkamp, and R. H. Hesselin. 1990. Fates of metal radiotracers added to a whole lake: Accumulation in fathead minnow (*Pimephales promelas*) and lake trout (*Salvelinus namaycush*). Water, Air and Soil Pollution. 52:277-293.

Hodson, P.V., B.R. Blunt and D.H. Spry. 1978. Chronic toxicity of water-borne and dietary lead to rainbow trout in (*Salmo gairdneri*) in Lake Ontario water. Water Res. 12-869-878.

Hodson, P.V., D.M. Whittle, P.T.S. Wong, U. Borgmann, R. L. Thomas, Y.K. Chau, J.O. Nriagu, and D.J. Hallett. 1984. Lead contamination of the Great Lakes and its potential effects on aquatic biota. IN: J.O. Nriagu and M.S. Simmons (eds.) Toxic Contaminants in the Great Lakes. John Wiley and Sons, Inc.

Holcombe, G.W., D.A. Beniot, E.N. Leonard and J.M. McKim. 1976. Long-term effects of lead exposure on three generations of brook trout (*Salvelinus fontinalis*). J. Fish. Res. Board Can. 33:1731-1741.

Jarvinen, A.W. and G.T. Ankley. 1999. Linkage of effects to tissue residues: development of a comprehensive database for aquatic organisms exposed to inorganic and organic chemicals. SETAC Technical Publication Series. SETAC Press. Society of Environmental Toxicology and Chemistry, Pensacola, FL.

Kilgour, B.W., C.B. Portt and D.G. Dixon. 1999. Moira River Impact Study: Detailed design to determine the impact of the former Deloro Mine Site on the Moira River System. Final Report submitted to Ontario Ministry of Environment.

Klaverkamp, J.F., M.A. Turner, S.E. Harrison, and R. H. Hesslein. Fates of metal radiotracers added to a whole lake: accumulation in slimy sculpin (*Cottus cognatus*) and white sucker (*Catostomus commersoni*). The Science of the Total Environment. 28:119-128.

Lanno, R.P., S.J. Slinger and J.W. Hilton. 1985. Maximum tolerable and toxicity levels of dietary copper in rainbow trout (*Salmo gairdneri* Richardson). Aquaculture 49: 257-268.

McGeachy, SM and DG Dixon. 1992. Whole-body arsenic concentrations in rainbow trout during acute exposure to arsenate. Ecotoxicol. Environ. Saf. 24: 301-308.

McGeachy, SM and DG Dixon. 1990. Effect of temperature on the chronic toxicity of arsenate to rainbow trout. Can. J. Fish Aquat. Sci. 47: 2228-2234.

Moore, J.W. and S. Ramamoorthy. 1984. Heavy metals in natural waters: Applied monitoring and impact assessment. Springer-Verlag, New York.

Pentreath, R.J. 1973. The accumulation from sea water of ^{65}Zn, ^{54}Mn, ^{58}Co and ^{59}Fe by the thornback ray, *Raja clavata* L. J. Exp. Mar. Biol. Ecol. 12: 327-334.

Rehwoldt, R. 1976. Distribution of selected metals in tissue samples of carp, *Cyprinus carpio.* Bulletin of Environmental Contamination and Toxicology. 15(3): 374-377.

Sorensen, EMB. 1976. Thermal effects of the accumulation of arsenic in green sunfish. Arch Environ. Contam. Toxicol. 4: 8-17.

Sreedevi, P., A. Suresh, B. Sivaramakrishna, B. Prabhavathi and K. Radhakrishnaiah. 1992. Bioaccumulation of nickel in the organs of the freshwater fish, *Cyprinus carpio*, and the freshwater mussel, *Lamellidens marginalis*, under lethal and sublethal nickel stress. Chemosphere 24: 29-36.

Swanson, S.M. 1985. Food-chain transfer of U-series radionuclides in a northern Saskatchewan aquatic system. Health Physics 49(5): 747-770.

Swanson, S.M. 1989. Results of the study of effects on the Rabbit Lake minewater spill, November 6-7, 1989. Saskatchewan Research Council Report No. E-2130-2-E-89. Prepared for Saskatchewan Environment, Mines Pollution Control Branch, Regina, Saskatchewan.

U.S. EPA. 1993. Guidance for assessing chemical contaminant data for use in fish advisories. Environmental Protection Agency Report EPA 823-R-93-002.

Udea, T. and M. Nakahara. 1983. Accumulation of Co by marine fish. Bulletin of the Japanese Society of Scientific Fisheries. 49(4):651-654.

Wood, C.M., WS Adams, GT Ankley, DR DiBona, SN Luoma, RC Playle, WC Stubblefield, HL Bergman, RJ Erickson, JS Mattice and CE Schlekat. 1997. Environmental toxicology of metals. Pp. 31-51 In Bergman, HL, Dorward-King EJ (eds.) Reassessment of metals criteria for aquatic life protection. SETAC Press, Pensacola, FL.

2.5 Fish Populations

A sentinel fish survey was the recommended approach for assessing the potential effects of mine-related metal concentrations on fish populations within the Moira River system (Kilgour *et al.* 1999). Sentinel species monitoring is a common and effective approach used to evaluate the effect of stressors (e.g., metals) on wild fish populations. The sentinel species approach evaluates the performance (e.g., growth, condition, reproductive parameters) of a sentinel fish species inhabiting a particular site of interest (e.g., downstream of the Deloro Mine Site), relative to reference and/or historical performance data. The underlying premise of the approach is that the status of the sentinel species is a reflection of the overall condition of the aquatic environment in which the fish resides (Munkittrick 1992).

The receiving environment within the Moira River system consists of both river and lake habitat. Consequently, separate sentinel species surveys were required because physical/chemical conditions and fish communities differ greatly between the river and the lake habitats.

2.5.1 Methods

2.5.1.1 Sentinel Species and Sampling Locations

Lake Habitat

White sucker (*Catostomus commersoni*) was chosen as the sentinel species for lake habitat of the Moira River system. White sucker was selected as a suitable sentinel species because:

- It occurs in both Moira Lake and Stoco Lake (Kilgour *et al.* 1999);
- It is a benthic feeder and utilizes deeper areas of lakes where metal-containing sediments accumulate (i.e., increased exposure);
- Gonadal development in the fall is sufficiently advanced to measure reproductive parameters such as gonad size and fecundity; and
- It has proven to be an effective sentinel species in numerous other studies (e.g., McFarlane and Franzin 1978, Swanson 1982, Trippel and Harvey 1987, Munkittrick and Dixon 1988, McMaster *et al.* 1991, Miller *et al.* 1992, Hodson *et al.* 1992, Gibbons *et al.* 1998).

The sampling locations for the sentinel survey were Moira Lake and Stoco Lake (exposed to mine-related metal concentrations), and Round Lake and Consecon Lake (reference locations) (Figure 2.5-1). However, capture success of white sucker in Stoco Lake during the fall collection trip was limited (see Section 2.5.2.1), and the Moira River at Bend Bay was included as an alternate exposure site. Photos of each lake and of Bend Bay are provided in Appendix V.

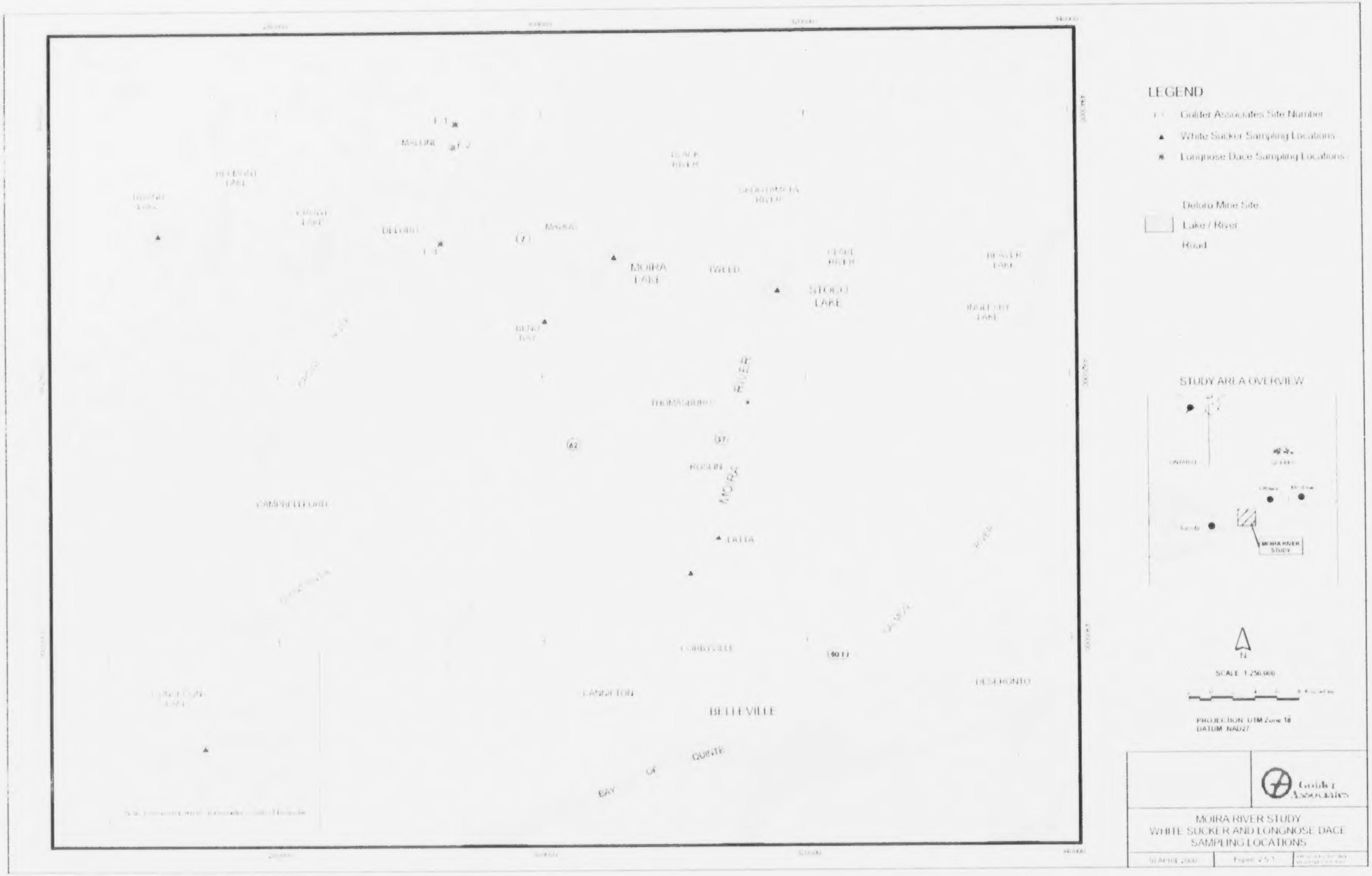
River Habitat

As suggested by Kilgour *et al.* (1999), and confirmed during a reconnaissance field survey, longnose dace (*Rhinichthys cataractae*) was selected as the sentinel species for the river habitat of the Moira River system. Longnose dace was a suitable sentinel species because:

- It is abundant and widely distributed in the upper reaches of the Moira River near Malone and the Deloro Mine Site;
- It is a riverine species which completes its life cycle within the Moira River (i.e., maximum exposure);
- It exhibits limited potential for large-scale movement among reference and exposure sites relative to larger fish species; and,
- Gonadal development in the fall is sufficiently advanced to measure reproductive parameters.

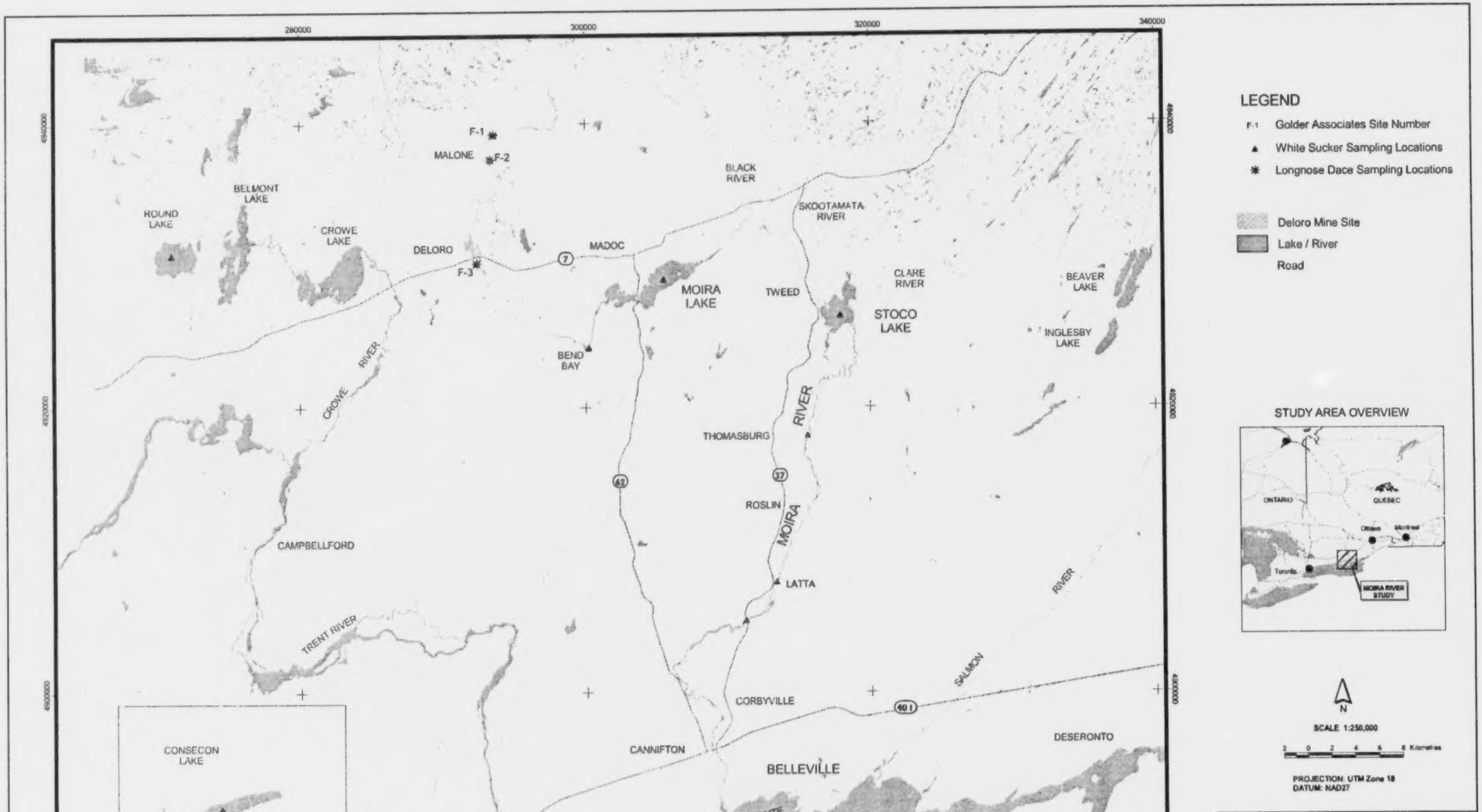
Longnose dace were collected from two reference sites upstream of the Deloro Mine Site and an exposure site immediately downstream of the mine (Figure 2.5-1). The general locations and UTM coordinates of each sampling site are provided in Table 2.5-1. The sites differ somewhat from sites used for sediment and invertebrate sampling. This is because the longnose dace sites had to be good longnose dace habitat, rather than the depositional areas that were chosen for sediment and invertebrate sampling.

Each site was dominated by riffle/run habitat with bedrock and cobble/boulder substrates (see photos - Appendix V). During the study period, all sites were influenced by low-water levels. This was particularly noticeable at reference site F-2. Rainfall near the end of the study period, and immediately prior to sampling the exposure site (F-3), resulted in a considerable increase in water level and flow. However, it is unlikely that whole-organism characteristics of longnose dace from site F-3 would have been affected by such a recent change in habitat conditions.


LEGEND
Golder Associates Site Number
White Sucker Sampling Locations
Longnose Dace Sampling Locations
Deloro Mine Site
Lake / River
Road
STUDY AREA OVERVIEW
MOIRA RIVER STUDY
N
SCALE 1:250 000
PROJECTION: UTM Zone 18
DATUM: NAD27
F-1
F-2
F-3
MALONE
DELORO
MADOC
MOIRA LAKE
TWEED
STOCO LAKE
BLACK RIVER
THOMASBURG
MOIRA
RIVER
ROSLIN
LATTA
CORBYVILLE
CANNIFTON
BELLEVILLE
DESERONTO
CAMPBELLFORD
BAY OF QUINTE
(7)
(62)
(37)
(401)
Golder Associates

MOIRA RIVER STUDY
WHITE SUCKER AND LONGNOSE DACE
SAMPLING LOCATIONS

10 APRIL 2000 | Figure 2.5.1


280000
300000
320000
340000
4940000
4920000
4900000
ROUND LAKE
BELMONT LAKE
CROWE LAKE
F-1
MALONE
F-2
DELORO
F-3
7
MADOC
BLACK RIVER
SKOOTAMATA RIVER
MOIRA LAKE
TWEED
CLARE RIVER
STOCO LAKE
BEAVER LAKE
INGLESBY LAKE
BEND BAY
CROWE RIVER
THOMASBURG
RIVER
37
43
ROSLIN
MOIRA
LATTA
CAMPBELLFORD
TRENT RIVER
RIVER
SALMON
CORBYVILLE
401
CANNIFTON
BELLEVILLE
DESERONTO
BAY OF QUINTE
CONSECON LAKE
Note: Consecon Lake is 18 kilometers south of Belleville
LEGEND
F-1 Golder Associates Site Number
▲ White Sucker Sampling Locations
✱ Longnose Dace Sampling Locations
Deloro Mine Site
Lake / River
Road
STUDY AREA OVERVIEW
ONTARIO
QUEBEC
Ottawa
Montreal
Toronto
MOIRA RIVER STUDY
N
SCALE 1:250,000
2 0 2 4 6 8 Kilometres
PROJECTION: UTM Zone 18
DATUM: NAD27

Golder Associates

MOIRA RIVER STUDY
WHITE SUCKER AND LONGNOSE DACE
SAMPLING LOCATIONS

10 APRIL 2000 | Figure 2.5-1 | PRODUCED BY BW
REVIEWED BY AR

R:\1999\1300\991-1358\8100Mapping\gis\apr\d-moira-april10.apr

Table 2.5-1
General Location and UTM Co-ordinates of Sampling Sites for Longnose Dace, Moira River, Fall 1999

Site	General Location	UTMs[a] of Sampling Site
F-1	Reference site at the bridge crossing upstream of Malone (approx. 10 km upstream of the Deloro Mine Site)	293520 E / 4939200 N
F-2	Reference site located immediately upstream of the bridge crossing in Malone (approx. 6.5 km upstream of the Deloro Mine Site).	293290 E / 4937440 N
F-3	Exposure site located immediately upstream of the bridge crossing on the old Marmora Road (approx. 2.5 km downstream from the Deloro Mine Site)	292350 E / 4930125 N

[a] Universal Transverse Mercator (UTM).

2.5.1.2 Fish Collections

Sentinel fish collections on the Moira River system were conducted during October 3-22, 1999. A minimum of 20 mature males and 20 mature females was the target sample size for each sample site. White sucker were collected with the assistance of the Ontario Ministry of the Environment (MOE). Sucker were collected using the MOE electrofishing boat (Smith-Root SR-12), as well as the Golder Associates Ltd. portable boat-electrofishing unit (Smith-Root GPP portable). Electrofishing effort was concentrated on the margin/backwater habitat of each lake, although passes through deeper pelagic zones were also made. Trap nets and gill nets (15.4 m x 0.9 m x 9 or 10.25 cm mesh size, 2-3 h sets) were also used to sample habitats that are difficult to sample using electrofishing gear. Neither netting technique was successful in capturing white sucker. Longnose dace were collected using a backpack electrofisher (Smith-Root Type VII) and dip nets. Collection of white sucker and longnose dace was conducted following detailed methods outlined in Golder Technical Procedure 8.1-3 “Fish Inventory Methods” (Appendix V). All fish species captured were identified and enumerated.

Each fish was anaesthetized prior to being processed by placing it in a 0.1 g/L solution of tricaine methanesulfonate (MS-222) for 30-60 seconds. Fish were removed from the anaesthetic and measured for total length, fork length, and fresh body weight. Fish were sacrificed by a sharp blow to the head and dissected to measure carcass (i.e., eviscerated) weight, gonad weight and liver weight. External and internal pathology examinations were conducted for each fish. Other information recorded included: gender, stage of sexual maturity, and results of a visual assessment of gut contents. All fish were processed according to methods described in Golder Technical Procedure 8.16-0 "Fish Health Assessment- Metals" (Appendix IV).

A sample of ovarian tissue from mature female sucker was removed from the mid-section of the right ovary, weighed (approx. 0.75-1.0 g) and preserved in Gillson's solution for fecundity analyses. For longnose dace, both ovaries were weighed and preserved in Gillson's solution. The total number of eggs per sample was counted, and these results were used to estimate the total number of eggs per fish (total fecundity). As well, the average diameter of 30 individual eggs/female was determined as an estimate of egg size.

Scales and pectoral fin rays were removed from white sucker for ageing (i.e., annulus count). Longnose dace were aged using otoliths and scales. Otoliths from longnose dace were aged using the "crack-and-burn" procedure. Briefly, the otolith is cut along the transverse axis and held in an alcohol flame to char the cut surface and enhance the visual identification of growth annuli. For both species, scales were used as secondary ageing structures and read, when required, from acetate imprints. Ageing structures were prepared and read by Northshore Environmental Services, Thunder Bay, Ontario. Ages were estimated following procedures outlined in Mackay *et al.* (1990).

2.5.1.3 Data Analyses

Statistical analysis of sentinel fish species data was done using SYSTAT® statistical software (Wilkinson 1990). Analysis of Variance (ANOVA) was used to compare fork length, body weight, egg diameter and age estimates among sites. Estimates of size-at-age (fork length vs. age), condition (carcass weight vs. fork length), gonad size, fecundity and liver size were evaluated using ANCOVA. With the exception of size-at-age, carcass (i.e., eviscerated) weight was used as a covariate to adjust for any differences in body size. Using carcass weight instead of body weight eliminated possible confounding effects of altered organ weight (e.g., gonad weight, liver weight) on the interpretation of variables related to body weight. An assumption of the ANCOVA model is that the slopes of the regression lines are equal between lakes/sites. Therefore, differences in slopes were tested prior to conducting the ANCOVA. Generally, ANCOVA is fairly robust even when slopes are not equal, so slopes were considered different when $p<0.01$ (Paine 1998). Following significant ANOVA or ANCOVA (intercepts) results, Tukey's procedure was used to identify specific differences among sites. Data were $\log_{10}$ transformed where appropriate and sexes were analyzed separately.

Outliers

Data were initially screened for potential outliers by visual examination of scatterplots and box plots. The procedure for removing outliers was based on the evaluation of Studentized Residuals (SR). Observations that were more than four standard deviations (i.e., SR>4) from the cell mean were removed and the analysis run again. If any new outliers (SR>4) occurred, they were also removed and the analysis was redone. No further outliers were deleted after this point. Adopting SR>4 as a cut-off is considered conservative, as greater than 99% of Studentized Residuals were expected to have lower values (Grubbs 1971).

Power Analysis

Power analysis was used to evaluate the possibility of false negative results i.e., concluding that no differences in fish performance exists when in fact they do. Peterman (1990) has argued that the consequences of false negatives may be greater than the dangers of false positives (i.e., concluding a difference when none exist), and that environmental impact assessments should have adequate statistical power to detect meaningful differences. In other words, it is necessary to determine whether a comparison that did not show a statistical difference actually had sufficient power (i.e., statistical strength) to detect a given difference, if one existed.

Statistical power is a function of sample size, variability and the magnitude of difference (i.e., effect size) one wishes to detect. The effect size is not easily defined. The Environmental Effects Monitoring program for the pulp and paper industry have set an effect size of ±25% difference in gonad weight (Environment Canada 1997). For the purposes of this study, parameter-specific sample sizes were estimated for an effect size of 20, 30, and 50% (i.e., differences between sites). The mean squared error (MSE) term from the ANOVA or ANCOVA statistical model provided the estimate of among-site-variance for each fish parameter. The probability of making a Type I error (i.e., α) was set at $\alpha=0.05$.

Because the study design for white sucker and longnose dace consisted of more than two sites, simple power equations comparing two samples could not be used. Cohen (1988) provides comprehensive methods for power analyses for more than two samples, and for a variety of statistical tests (e.g., ANOVA, ANCOVA). Power analyses were conducted using G*Power software (Faul and Erdfelder 1992), that performs computations based on methods described by Cohen (1988).

Statistical comparisons were considered to have sufficient power (P, probability of detecting an effect size) when P≥0.80 (Environment Canada 1997).

2.5.2 Results and Discussion

2.5.2.1 White Sucker

Capture success of mature white sucker was variable among sites (Table 2.5-2). In general, capture success of female white sucker was higher than male sucker, although in Stoco Lake and Bend Bay, both sexes were difficult to collect in high numbers. Relative to the reference lakes, the greatest capture success of adult sucker was in Moira Lake – one of the sites exposed to metals from the Deloro Mine Site (see Sections 2.1, 2.2). A summary of incidental fish species captured in each lake during the collection of white sucker is provided in Appendix V.

Table 2.5-2
Total Number of Female, Male and Immature White Sucker Captured from Lake Habitat, Moira River System, Fall 1999

Sex	Reference Lake		Exposure Lake/Site		
	Consecon	Round	Moira	Stoco	Bend Bay
Female	21	16	22	3	11
Male	9	7	18	8	8
Immature	15	37	6	20	8
Total	45	60	46	31	27

Due to limited sample sizes, statistical analyses of fish parameters were restricted to data from Consecon, Round and Moira lakes. Emphasis was placed on analyses of female sucker because of larger sampler sizes. Analyses of male sucker were done to see if they supported results of female sucker, although definitive conclusions were not possible due to low sample sizes. Data from Bend Bay (males and females) and Stoco Lake (males only) were included in all graphs of fish parameters to provide some perspective on how they compared with exposure/reference sites.

Fish Measurements

Based on internal/external pathology examinations of white sucker, the incidence of abnormalities ranged from 95-100% per site (Table 2.5-3). Most observed abnormalities were associated with the gills (marginate lamellae, fish lice infestation) or related to internal parasitism. There was no clear evidence indicating that the prevalence of abnormalities was different between reference and exposed populations of white sucker.

Table 2.5-3
Number of Adult White Sucker with Specific External/Internal Abnormalities, Lake Habitat, Moira River System, Fall 1999

Abnormality	Reference Lake		Exposure Lake/Site		
	Consecon	Round	Moira	Stoco	Bend Bay
Eyes – opaque (1 eye)	0	0	0	0	2
Gills – frayed and marginate	1	0	0	0	0
– marginate	17	5	16	5	6
– marginate and pale	1	0	0	0	0
Skin – lesions	7	0	7	0	3
– tumors	2	0	0	0	0
– re-oriented scales	1	0	1	2	1
Fins – light active erosion	2	0	5	0	0
– moderate erosion/ some hemorrhaging	1	0	0	0	0
Opercula – mild shortening	3	0	1	1	2
Hindgut – mild inflammation	8	0	0	2	0
Liver – cysts or nodules	0	1	0	0	1
– discoloration	6	1	1	0	0
Parasites – lice[a] - gill/gill cavity	22	9	31	10	14
– tapeworms	4	7	2	2	3
– nematodes	0	6	5	0	0
– internal parasites [b]	17	21	21	6	12
Total No. of fish evaluated	30	23	40	11	19
% affected[c]	100	96	95	100	95

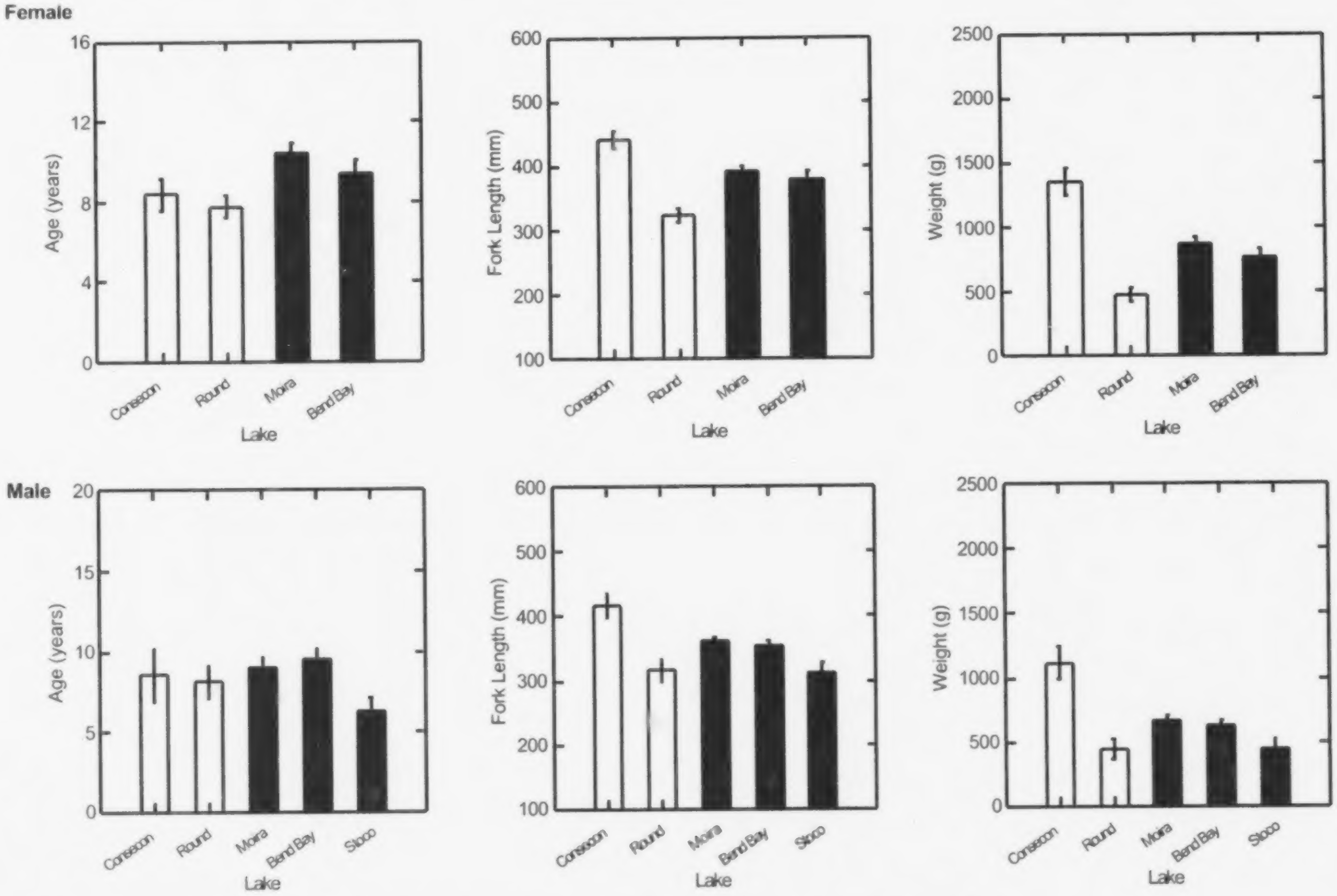
[a] Fish lice, parasitic crustacean (Copepoda).

[b] Unknown parasites of intestinal tract, liver and heart; white cysts - possibly a trematode.

[c] An individual fish may exhibit more than one type of abnormality.

Variations in age, body size, size-at-age and organ metrics for white sucker from each study lake are presented in Figures 2.5-2 to 2.5-5. Results of overall ANOVA and ANCOVA statistical comparisons among lake populations of white sucker are presented in Table 2.5-4.

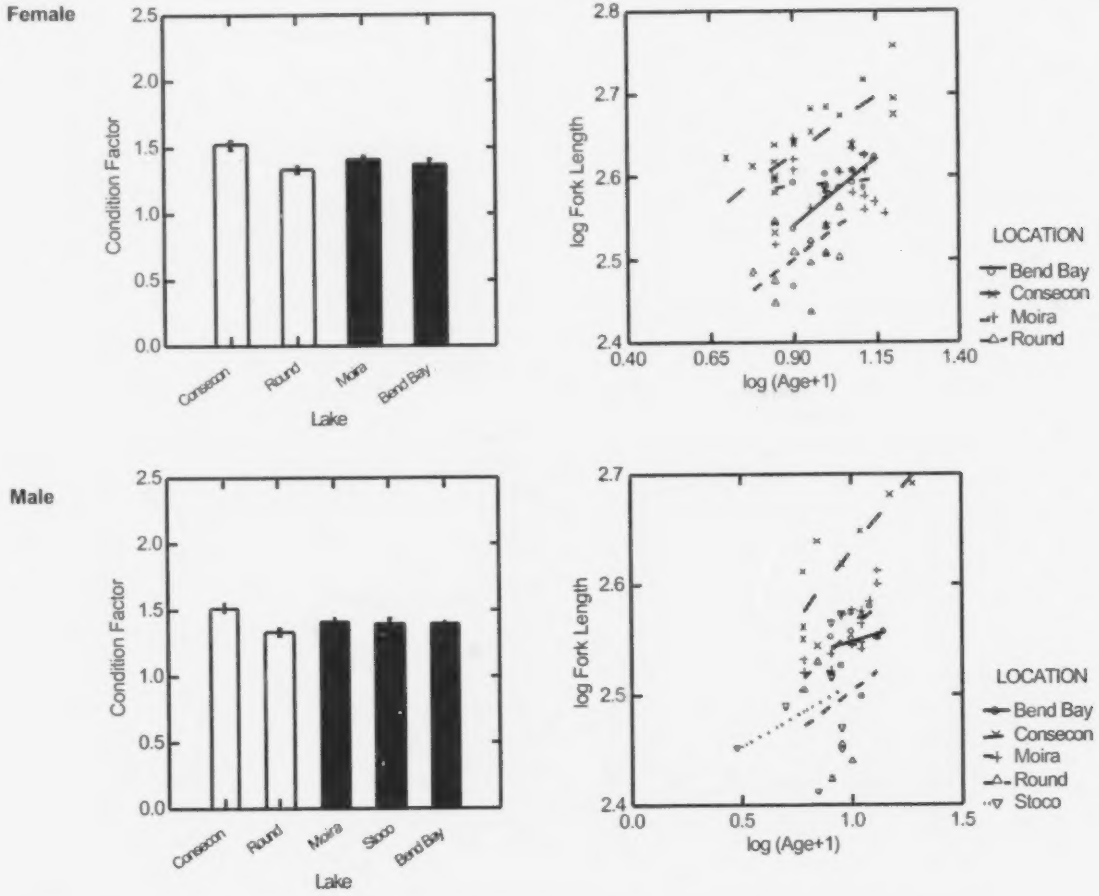
Figure 2.5-2
Mean Age, Fork Length and Body Weight of Female and Male White Sucker, Moira River System, Fall 1999[a]



[a] Values represent mean ± S.E. Open bars are reference populations, solid bars are exposed populations.

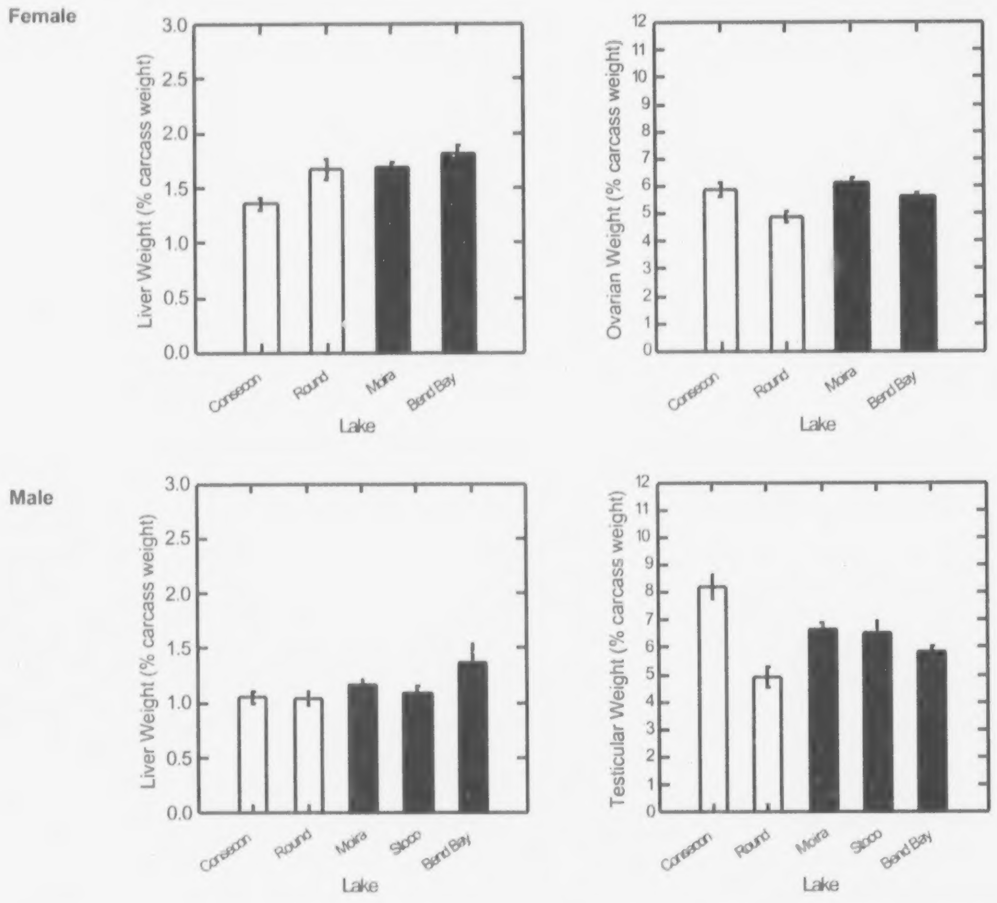
Figure 2.5-3

Condition and Size-at-Age of Female and Male White Sucker, Moira River System, Fall 1999[a]



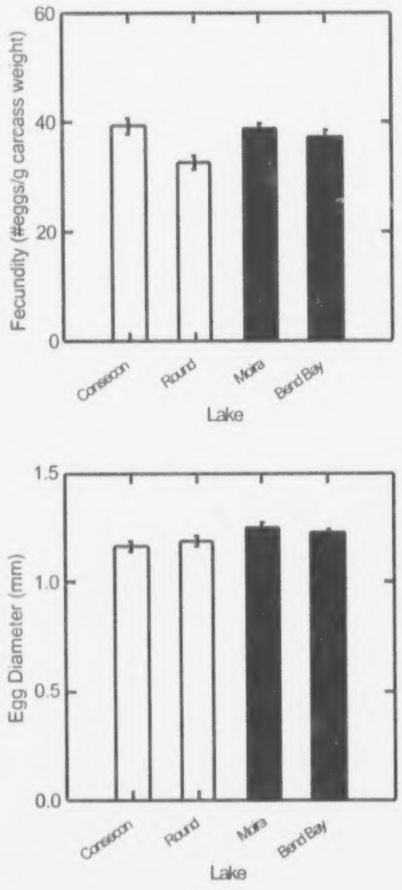
[a] Values represent mean ± S.E. Open bars are reference populations, solid bars are exposed populations.

Figure 2.5-4
Relative Liver and Gonad Weights of Female and Male White Sucker, Moira River System, Fall 1999[a]



[a] Values represent mean ± S.E. Open bars are reference populations, solid bars are exposed populations.

Figure 2.5-5
Fecundity and Mean Egg Size of Mature Female White Sucker, Moira River System, Fall 1999[a]



[a] Values represent mean ± S.E. Open bars are reference populations, solid bars are exposed populations.

Results of Tukey's pairwise tests comparing the performance of white sucker populations from Consecon, Round and Moira lakes are presented in Table 2.5-5. The percent difference was included in Table 2.5-5 to provide a better understanding of the magnitude of difference in individual fish characteristics.

Table 2.5-4
Results of Overall ANOVA and ANCOVA Tests Comparing Whole-Organism Characteristics of White Sucker Among Reference and Exposed Lakes, Moira River System, Fall 1999

Sex	Parameter	ANOVA[a]	ANCOVA[b]	
		Mean	Slope	Intercept
Female	Fork length	<0.001		
	Body weight	<0.001		
	Condition		0.14	<0.001
	Mean age	0.007		
	Size-at-age		0.03	<0.001
	Gonad weight		0.99	0.011
	Fecundity		0.51	<0.001
	Egg diameter 0	.007		
	Liver weight		0.08	0.002
Male	Fork length	<0.001		
	Body weight	<0.001		
	Condition		0.06	0.04
	Mean age	0.59		
	Size-at-age		0.70	<0.001
	Gonad weight		0.74	0.04
	Liver weight		0.13	0.45

(a) Probability value for testing an overall difference among means.
(b) Probability value for testing an overall difference among slopes and intercepts means.

Table 2.5-5
Summary of Statistical Analyses Comparing the Performance of White Sucker Populations from Lake Habitats, Moira River System, Fall 1999

Sex	Variable	Round *vs* Consecon		Round *vs* Moira		Consecon *vs* Moira	
		P-value[a]	% Difference	P-value	%[b] Difference	P-value	% Difference
Females	Fork length	<0.001	+36.4	<0.001	+21.8	0.004	-10.7
	Body weight	<0.001	+188.7	<0.001	+91.8	<0.001	-33.6
	Condition	0.001	+16.5	0.23	+5.5	0.002	-9.4
	Mean age	0.88	+4.7	0.012	+31.8	0.029	+25.9
	Size-at-age	<0.001	+34.9	<0.001	+14.5	<0.001	-15.1
	Gonad weight	0.99	-0.91	0.13	+13.2	0.04	+14.3
	Fecundity	0.004	+29.7	<0.001	+27.2	0.92	+1.9
	Egg diameter	0.70	-2.0	0.087	+5.6	0.006	+7.8
	Liver weight	0.061	-19.0	0.99	+1.1	<0.001	+24.7
Males	Fork length	<0.001	+31.7	0.010	+14.8	0.005	-12.9
	Body weight	<0.001	+159.5	0.004	+59.4	0.001	-38.6
	Condition	0.035	+13.2	0.22	+5.9	0.11	-6.4
	Mean age	No Significant Difference, $p=0.59$[c]					
	Size-at-age	<0.001	+32.2	0.004	+12.4	<0.001	-15.0
	Gonad weight	0.03	+40.5	0.08	+21.6	0.21	-13.4
	Liver weight	No Significant Difference, $p=0.45$[c]					

[a] P-values are from Tukey's pairwise comparisons (following a significant ANOVA/ANCOVA F-statistic).

[b] % Difference is for exposed relative to the reference site (or Consecon Lake relative to Round Lake) calculated using ANOVA/ANCOVA adjusted least squared means.

[c] P-value from ANOVA/ANCOVA model testing for differences in intercepts among all sites.

Comparison of Reference Populations (Consecon Lake vs Round Lake)

Consecon Lake and Round Lake were chosen as reference lakes based on similarities in water chemistry, trophic level, cottage development, and general fish community composition (see Section 1.4). However, there were significant differences in whole-organism characteristics of white sucker populations from these lakes.

There was no difference in mean age of male and female sucker between lakes, although statistical power for male sucker was poor (Table 2.5-6). Sucker from Consecon Lake were longer, heavier, and had increased growth (as estimated by size-at-age) relative to sucker from Round Lake (Figures 2.5-2, 2.5-3). Condition of sucker from Consecon Lake was also higher, indicating they were heavier at any given length (i.e., fatter) (Figure 2.5-3). Liver weight was lower in female sucker from Consecon, although no difference was observed in male sucker (Figure 2.5-4), despite sufficient power to detect a difference of at least 30% (Table 2.5-6).

Table 2.5-6
Statistical Power to Detect a Difference of 20, 30 and 50% (ES, effect size) for Those Comparisons of White Sucker That Were Not Statistically Different

Sex	Variable	ES=20%	ES=30%	ES=50%
Male	Mean age	0.21	0.40	0.78
	Liver weight	0.62	0.91	0.99

* Power based on ANOVA/ANCOVA model including all three sites.

Testis weight was greater in sucker from Consecon Lake, although there was no difference in ovary weight or egg size (i.e., diameter) (Figures 2.5-4, 2.5-5). Interestingly, fecundity was approximately 30% higher at Consecon Lake (Figure 2.5-5) suggesting that individual eggs from sucker of Round Lake were heavier or denser.

In general, white sucker from Consecon Lake showed evidence of increased energy expenditure and storage relative to sucker from Round Lake. This is commonly a response to increased food availability and can occur for several reasons, such as relaxed competition or increased food productivity (Gibbons and Munkittrick 1994). The reason for the observed difference in fish performance is uncertain, although benthic community structure does not appear to be markedly different between lakes (see Section 2.3). Oxygen depletion occurs in the deeper areas of Consecon Lake, but does not occur in Round Lake. Oxygen depletion would be expected to decrease available habitat (and potentially release more metals from sediments), creating more unfavourable conditions. However, the white sucker from Consecon Lake showed no evidence of decreased growth or reproductive capacity relative to Round Lake; in fact, the opposite was true. The results are important in that they emphasize the degree of reference variability in the performance of white sucker and provide a baseline from which to evaluate the health status of white sucker from Moira Lake.

Exposed (Moira Lake) vs. Reference Populations

The response of the white sucker population from Moira Lake was compared to populations from Consecon Lake and Round Lake. Based on differences observed between the reference lakes, it was not surprising that the relative response of exposed fish from Moira Lake also differed.

Female sucker from Moira Lake were older relative to sucker from both reference lakes (Figure 2.5-2). There was no difference in male age, although there was insufficient power to detect even a 50% difference in age (Table 2.5-6).

Both male and female sucker from Moira Lake were generally longer, heavier and had increased growth (i.e., size-at-age) relative to sucker from Round Lake; whereas, they were shorter, lighter and had decreased growth relative to sucker from Consecon Lake (Figures 2.5-2, 2.5-3). There was no difference in condition between exposed and reference sucker (Figure 2.5-3).

Liver size of females from Moira Lake was greater than observed at Consecon Lake, but similar to females from Round Lake (Figure 2.5-4). There was no difference in male liver size.

Ovary weight was greater at Moira Lake relative to either reference population; however, testis weight was intermediate between Round and Consecon lakes (Figure 2.5-4). Fecundity was higher in sucker from Moira Lake relative to Round Lake, but similar to estimates obtained from Consecon Lake (Figure 2.5-5). There were no differences in mean egg diameter among sites (Figure 2.5-5).

The evaluation of the health status of white sucker from Moira Lake depends on what reference population is used for comparison (Table 2.5-7). If the population from Round Lake was selected then one would conclude that sucker from Moira Lake were older and showed increased energy expenditure (e.g., increased size, growth, reproductive effort), but no change in energy storage (condition, liver size). Conversely, relative to Consecon Lake, sucker from Moira Lake were older, had decreased energy expenditure (size, growth), and no change (condition) or an increase in energy storage (female liver size). In many instances, whole-organism characteristics of sucker from Moira Lake were intermediate between Consecon and Round lakes.

Table 2.5-7
Summary of the Whole-Organism Response of White Sucker from Moira Lake, Moira River System, Fall 1999

Variable	Moira vs Round		Moira vs Consecon	
	Females	Males	Females	Males
Fork length	+	+	-	-
Body weight	+	+	-	-
Condition	O	O	O	O
Mean age	+	O[a]	+	O[a]
Size-at-age	+	+	-	-
Gonad weight	+	+	+	-
Fecundity	+	na	O	na
Egg diameter	O	na	O	na
Liver weight	O	O	+	O

+ signifies a increase relative to reference data, - signifies a decrease, O signifies no change.
na - not applicable.
[a] comparisons of male age did not have sufficient power to detect differences <50%.

If one accepts that white sucker populations from both Consecon Lake and Round Lake represent natural reference variability in fish performance, then the only characteristic of exposed white sucker that is consistently different (same direction) from both reference conditions is an older age structure in females. Whether this difference is related to metals is unknown, but an increase in mean adult age often results from increased juvenile and/or early life-stage mortality or decreased recruitment (Munkittrick and Dixon 1989). Conversely, mean age at the reference lakes may be lower due to increased adult mortality (e.g., recreational angling). A more thorough evaluation of age structure (not just limited to adult age classes) would provide better resolution to assess possible differences in age structure.

Whole body arsenic concentrations in white sucker were significantly higher in Bend Bay, Moira Lake and Stoco Lake (see Section 2.4). Other elevated metal concentrations in white sucker were silver in Bend Bay; cobalt in Bend Bay and Moira Lake; copper in Bend Bay; and, uranium in Stoco Lake. These data confirmed that white sucker populations in Bend Bay, Moira Lake and Stoco Lake were, indeed, exposed to metals of concern.

It is possible that fish that are chronically exposed to elevated metal concentrations in the Moira River system have become tolerant. Laboratory studies have shown that rainbow trout (*Oncorhynchus mykiss*) gradually increased their tolerance to arsenic during exposure to 0.22 of the lethal concentration (Dixon and Sprague 1981). Rainbow trout exposed to 10-20 mg/kg As in their diet (an order of magnitude above observed fish tissue concentrations in the Moira River system) did not differ in growth from controls (Oladimeji *et al.* 1984). Mortality of rainbow trout exposed for 28 days to 100 and 1000 µg/L As did not increase (Spehar *et al.* 1980).

Field studies specifically documenting the effects of elevated arsenic and metal concentrations on wild white sucker populations are rare. Three studies are summarized and compared to this study in Table 2.5-8. Metals of concern and the concentrations of those metals differ among the studies. Copper is the only metal in common among all studies and concentrations of copper are similar. The Moira River system has the greatest number of metals of concern and is the only study with elevated arsenic. Hardness and pH (when reported) are relatively similar. Lake morphometry differs significantly among the studies and important variables such as relative abundance of the food supply also vary (e.g., there was no evidence of limitation in food supply in Hamell Lake, but food supply was definitely limited in Beaverlodge Lake and food quality differed among Manitouwadge lakes). Observed effects in white sucker populations are different in each study, illustrating how difficult it is to relate specific responses in natural populations to specific toxicants.

Table 2.5-8
Comparison of Effects Observed in White Sucker Populations at Sites with Elevated Metal Concentrations

Study Location	Metal Concentrations* (µg/L)	Effects Observed	Reference
Moira Lake, Ontario	As: 14 - 160 (1964-1999) Co: 0.9 - 3 (1988-1999) Cu: 1 - 9 (1981-1999) Pb: 3 - 5 (1981-1999) Ni: 3 - 10 (1988-1999) Hardness: 129 - 169 mg/L $CaCO_3$ pH: 7.7 - 8.3	Most whole-organism characteristics within the range of reference populations except an increase in mean age of females.	This study.
Hamell Lake, Saskatchewan	Cu: 10 - 20 Cd: 0.2 - 1.1 Zn: 141 - 341 Hardness: not reported pH: 7.3	Increased growth, fecundity and earlier age of maturation. Decreased spawning success, larval and egg survival, egg size, and longevity.	McFarlane and Franzin 1978.
Manitouwadge District, Ontario	Cu: 13 - 15 Zn: 209 - 253 Hardness: 108 - 112 mg/L $CaCO_3$ pH: 6.9 - 7.1	Smaller, shorter fish. Decreased egg size and fecundity; no increase in fecundity with age and increased spawning failure.	Munkittrick and Dixon 1988.
Beaverlodge Lake, Saskatchewan	U: 338 ± 193 As: <5 Cu: 9 - 46 Hardness: ≈ 70 mg/L $CaCO_3$ pH: 7.8 - 8.2	Missing juvenile and older mature size and age classes. Slower growth; delayed maturity.	Swanson 1982.

* Mean annual concentrations in Moira Lake.

Stoco Lake and Bend Bay (other exposed populations)

Although Stoco Lake and Bend Bay were not included in statistical analyses, data from these sites were included in Figures 2.5-2 to 2.5-5 to evaluate how they compared with Moira Lake and both reference lakes.

In general, white sucker from Bend Bay mirrored the response of sucker from Moira Lake. The response of male sucker from Stoco Lake was more variable (e.g., age, length, weight), although the overall response was not markedly different from other exposed lakes. As with Moira Lake, most parameters for sucker from Stoco Lake and Bend Bay were within the range of reference variation defined by Consecon Lake and Round Lake.

2.5.2.2 Longnose Dace

The abundance of female, male and immature longnose dace captured at the exposure site (F-3) and reference sites (F-1, F-2) is presented in Table 2.5-9. With the exception of male dace from the upper reference site (n=15), capture success of adult dace was good at each site. Relative abundance of longnose dace, as estimated by catch-per-unit-effort (CPUE), was not substantially different among reference sites (1.6 *vs* 1.8 adult dace/100 seconds electrofished). Unfortunately, CPUE could not be estimated for site F-3 because weather conditions caused the timer display on the electrofisher to malfunction. A summary of incidental fish species captured at each site during the collection of longnose dace is provided in Appendix V.

Table 2.5-9
Total Number of Female, Male and Immature Longnose Dace from River Habitat, Moira River System, Fall 1999

Sex	Reference Sites		Exposure Site
	F-1	F-2	F-3
Female	25	19	20
Male	15	20	20
Immature	46	82	10
Total	86	121	50

F-l = reference site upstream of Malone; F-2 = reference site in Malone; F-3 = exposure site downstream of the Deloro Mine Site (old Marmora Road).

Fish Measurements

Results of internal/external pathology examinations of longnose dace indicated that abnormalities were found in 65-100% of dace per site (Table 2.5-10). The presence of external black spots and small, white cysts within the body cavity were the most prevalent abnormality. Both abnormalities are probably parasitic in origin. Raised black spots in the skin are commonly a sign of infestation by a trematode (*Digenea*) that uses fish as an intermediate host as part of its life cycle (i.e., black spot disease) (Post 1987). The parasite associated with the internal white cysts was not identified; however, small larvae were found inside the cysts that may be indicative of trematode infestation. In general, there was no evidence suggesting that the prevalence of abnormalities/parasitism was different between reference and exposed populations of longnose dace.

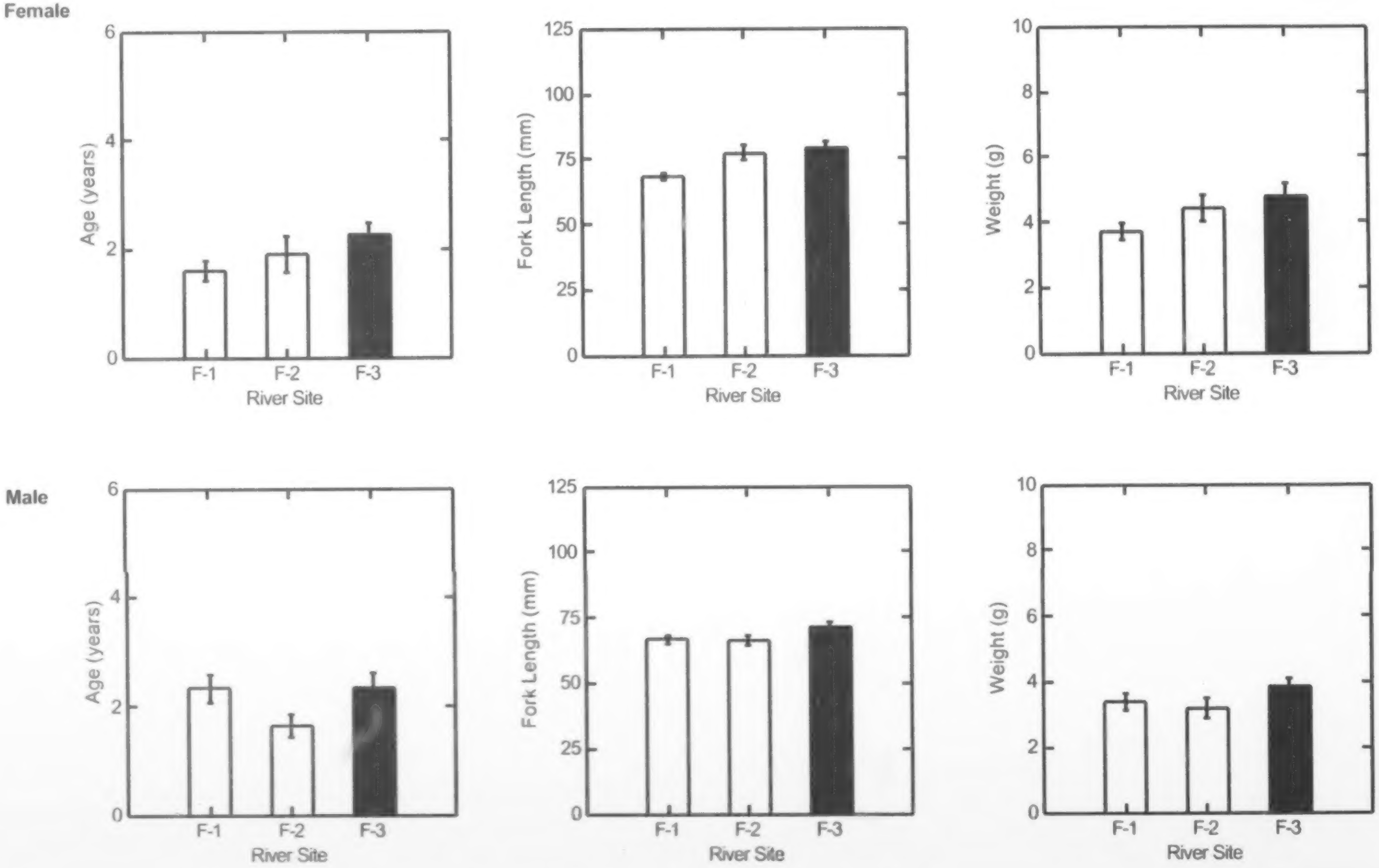
Table 2.5-10
Number of Longnose Dace with Specific External/Internal Abnormalities, River Habitat, Moira River System, Fall 1999

Abnormality	Reference Site		Exposure Site
	F-1	F-2	F-3
Eyes – swollen	1	1	0
Pseudobranchs – inflamed	0	1	0
Thymus – mild hemorrhages	2	1	0
Skin – lesions	0	0	2
Fins – light active erosion	1	3	2
Spleen – enlarged	1	0	1
Kidney – swollen	1	0	0
Kidney – fluid filled	1	4	0
Parasites – black spot(a)	40	6	16
Parasites – white cysts(b)	36	19	6
Total No. of fish evaluated	40	40	40
% affected(c)	100	73	65

(a) Digenean trematode.
(b) probable trematode infestation.
(a) An individual fish may exhibit more than one type of abnormality.
F-I = reference site upstream of Malone; F-2 = reference site in Malone; F-3 = exposure site downstream of the Deloro Mine Site (old Marmora Road).

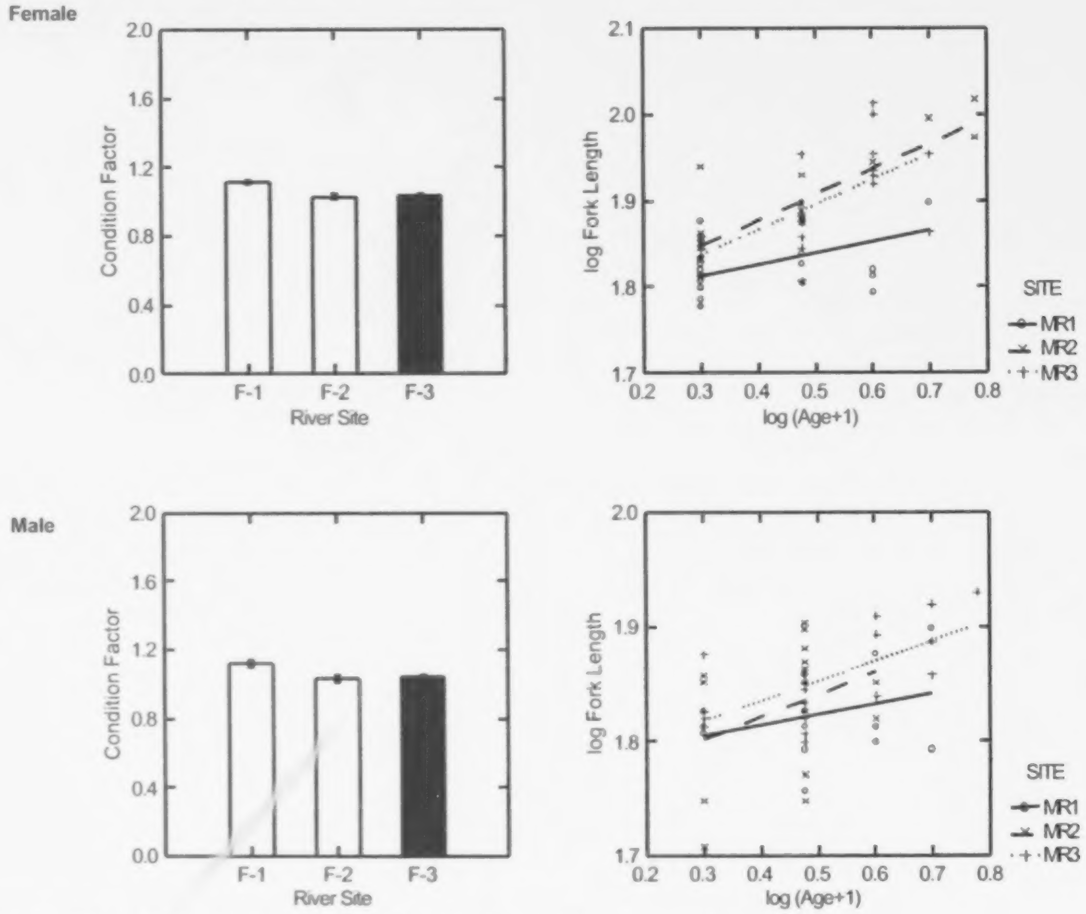
Variations in age, body size, size-at-age and organ metrics for longnose dace from each study site are presented in Figures 2.5-6 to 2.5-9. Results of overall ANOVA and ANCOVA statistical comparisons among populations of longnose dace are presented in Table 2.5-11. Results of specific Tukey's pairwise tests comparing the performance of dace populations between sites F-1, F-2 and F-3 are presented in Table 2.5-12. The percent difference was included in Table 2.5-12 to highlight the magnitude of difference in individual fish characteristics.

Figure 2.5-6
Mean Age, Fork Length and Body Weight of Female and Male Longnose Dace, Moira River System, Fall 1999[a]



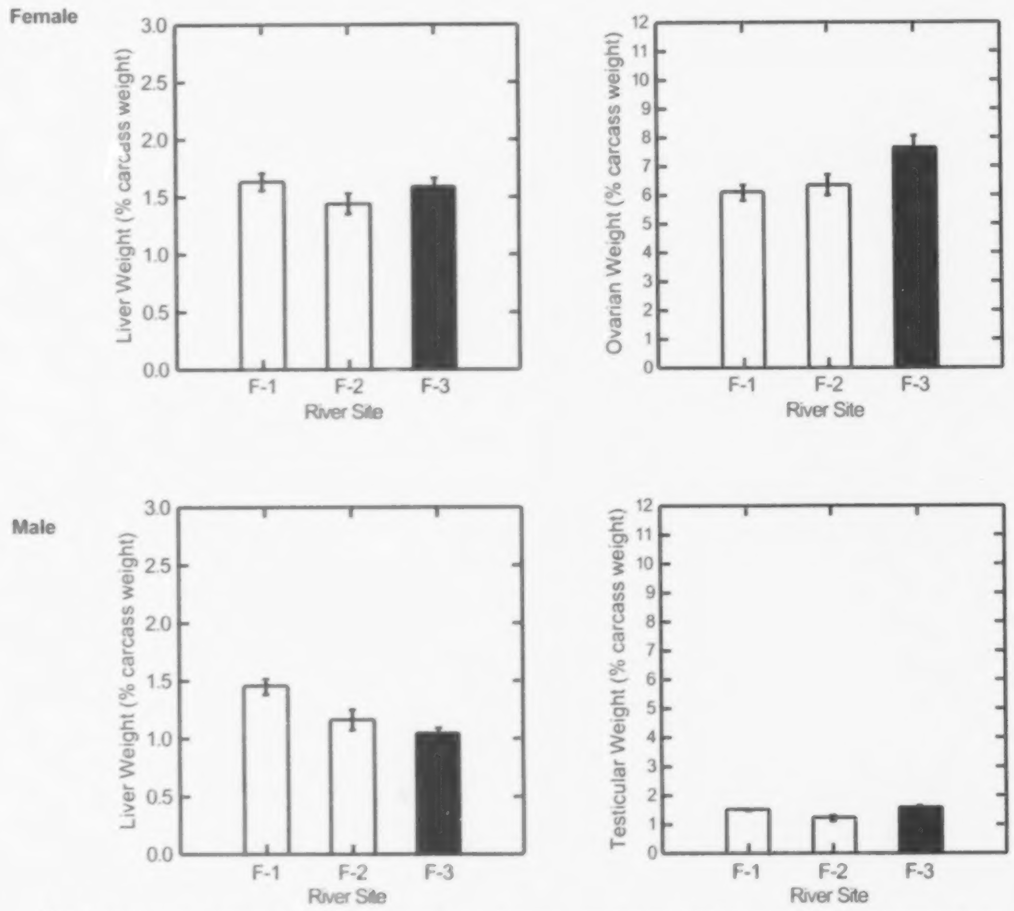
[a] Values represent mean ± S.E. Open bars are reference populations, solid bars are exposed populations.

Figure 2.5-7
Condition and Size-at-Age of Female and Male Longnose Dace, Moira River System, Fall 1999[a]



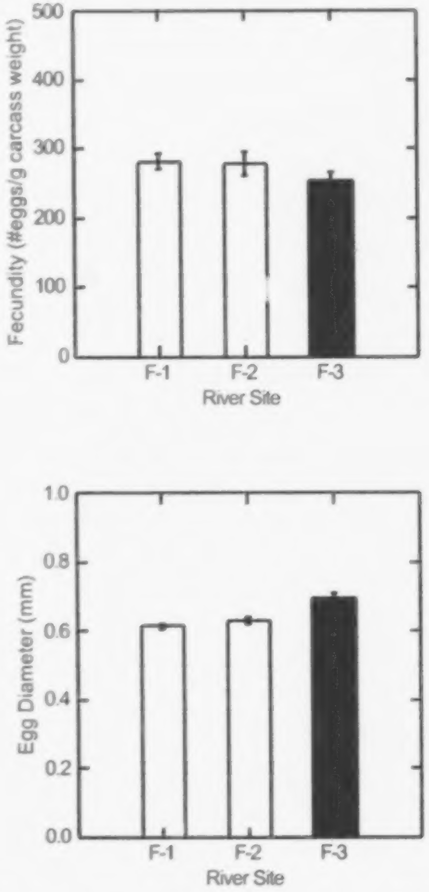
[a] Values represent mean ± S.E. Open bars are reference populations, solid bars are exposed populations.

Figure 2.5-8
Relative Liver and Gonad Weights of Female and Male Longnose Dace, Moira River System, Fall 1999[a]



[a] Values represent mean ± S.E. Open bars are reference populations, solid bars are exposed populations.

Figure 2.5-9
Fecundity and Mean Egg Size of Mature Female Longnose Dace, Moira River System, Fall 1999[a]



[a] Values represent mean ± S.E. Open bars are reference populations, solid bars are exposed populations.

Table 2.5-11
Results of Overall ANOVA and ANCOVA Tests Comparing Whole-Organism Characteristics of Longnose Dace Among Reference and Exposed River Sites, Moira River System, Fall 1999

Sex	Parameter	ANOVA[a]	ANCOVA[b]	
		Mean	Slope	Intercept
Female	Fork length	<0.001		
	Body weight	0.007		
	Condition		0.22	0.003
	Mean age	0.08		
	Size-at-age		0.09	<0.001
	Gonad weight		0.03	0.12
	Fecundity		0.09	0.08
	Egg diameter	<0.001		
	Liver weight		0.06	0.35
Male	Fork length	0.06		
	Body weight	0.07		
	Condition		0.07	0.02
	Mean age	0.52		
	Size-at-age		0.66	0.11
	Gonad weight		0.25	0.19
	Liver weight		0.44	0.003

[a] probability value for testing an overall difference among means.

[b] probability value for testing an overall difference among slopes and intercepts means.

Table 2.5-12
Summary of Statistical Analyses Comparing the Performance of Longnose Dace Populations from River Habitats, Moira River System, Fall 1999

Sex	Variable	F-1 vs F-2		F-1 vs F-3		F-2 vs F-3	
		P-value[a]	%[b] Difference	P-value	% Difference	P-value	% Difference
Females	Fork length	0.007	+12.6	0.001	+15.0	0.86	+2.1
	Body weight	0.05	+31.7	0.009	+41.2	0.84	+7.2
	Condition	0.003	-6.4	0.048	-4.5	0.53	+2.0
	Mean age	No Significant Difference, p=0.08[c]					
	Size-at-age	0.003	+12.6	0.002	+10.7	0.84	-1.7
	Gonad weight	No Significant Difference, p=0.12[c]					
	Fecundity	No Significant Difference p=0.08[c]					
	Egg diameter	0.45	+2.9	<0.001	+13.0	0.001	+9.8
	Liver weight	No Significant Difference, p=0.35[c]					
Males	Fork length	No Significant Difference, p=0.06[c]					
	Body weight	No Significant Difference, p=0.07[c]					
	Condition	0.012	-7.1	0.28	-3.8	0.32	+3.5
	Mean age	No Significant Difference, p=0.52[c]					
	Size-at-age	No Significant Difference, p=0.11[c]					
	Gonad weight	No Significant Difference, p=0.19[c]					
	Liver weight	0.098	-0.8	0.002	-1.3	0.25	-0.6

[a] P-values are from Tukey's pairwise comparisons (following a significant ANOVA/ANCOVA F-statistic).

[b] % Difference is for exposed relative to the reference site (or F-2 relative F-1) calculated using ANOVA/ANCOVA adjusted least squared means.

[c] P-value from ANOVA/ANCOVA model testing for differences in intercepts among all sites.

Comparison of Reference Populations (F-1 vs. F-2)

Reference sites located upstream and within the village of Malone were selected based on similarities in habitat characteristics (Photos V.6, V.7, Appendix V). Few differences in whole-organism characteristics of longnose dace were observed between these sites; this result was expected given the similarity in habitat.

Mean age of male and female dace was not significantly different between reference sites (Figure 2.5-6), although statistical power for both sexes was limited (Table 2.5-13) and unable to detect a difference of a factor of <1.38. Female dace from site F-2 were longer, heavier and had increased growth relative to females from F-1 (Figure 2.5-6, 2.5-7). Although overall tests of male length and weight were borderline (all sites included, Table 2.5-11), Tukey's pairwise comparisons between reference sites did not indicate significant differences (length, P=0.93; weight, P=0.53). As with age, the power of the comparison of male weight was unable to detect a difference of a factor of <1.38 (Table 2.5-13). Condition was statistically different between sites; however, the magnitude of difference was only 6-7% (Figure 2.5-7). No differences were observed in gonad weight, fecundity, egg size, and liver size (Figure 2.5-8, 2.5-9).

Table 2.5-13
Statistical Power to Detect a Difference of 20, 30 and 50% (ES, effect size) for Those Comparisons of Longnose Dace That Were Not Statistically Different

Sex	Variable	ES=20%	ES=30%	ES=50%
Female	Mean age	0.33	0.61	0.95
	Gonad weight	1.0	1.0	1.0
	Fecundity	0.59	0.89	0.99
	Liver weight	0.99	1.0	1.0
Male	Fork length	0.99	1.0	1.0
	Body weight	0.28	0.52	0.90
	Mean age	0.32	0.60	0.94
	Size-at-age	0.99	1.0	1.0
	Gonad weight	1.0	1.0	1.0

* power based on ANOVA/ANCOVA model including all three sites.

In general, female dace from site F-2 showed some evidence of increased energy expenditure, although there was no concomitant increase in gonad size, fecundity or estimates of energy storage (e.g., condition, liver size). As well, no whole-organism differences were observed in male dace between sites, although statistical power was relatively poor.

Exposed (F-3) vs. Reference Populations

The response of exposed longnose dace (site F-3) was defined relative to populations from upstream reference sites F-1 and F-2.

With the exception of a 10% increase in egg diameter at the exposed site (Figure 2.5-9), there were no significant differences in whole-organism characteristics between adult dace collected downstream of the mine site relative to dace from reference site F-2 (Figures 2.5-6 to 2.5-9). Not surprisingly, when dace from the exposure site were compared to dace from site F-1, the response mirrored the response of dace from site F-2 relative to site F-1 (i.e., reference site comparison) (Figures 2.5-6 to 2.5-9). Consequently, there is little evidence that whole-organism characteristics of longnose dace collected downstream of the Deloro Mine Site are different from dace collected from reference sites not influenced by the Deloro Mine Site.

Longnose dace are commonly found in riffles and higher velocity areas consisting of coarse substrates and boulders. As such, they are not in direct contact with fine sediments that accumulate higher concentrations of metals downstream of the mine (Section 2.2.). However, the observed increase in tissue burden of metals (particularly arsenic, copper, nickel, mercury and silver) downstream of the Deloro Mine Site (Section 2.4) provides assurance that longnose dace are exposed to increased metal concentrations.

Despite the exposure (and uptake) of these heavy metals, whole-organism characteristics of longnose dace did not reflect the increase in metal concentrations. It is possible that concentrations were not high enough to cause individual or population level changes in resident fishes. Alternatively, longnose dace may not be sensitive to metals. Longnose dace has been successfully used to monitor the effects of bleached kraft mill effluent and municipal sewage wastewater (Golder 2000), but it is unknown whether they have been previously used to investigate the effects of metals. Finally, it is also possible that several stressors are impacting the same site in opposite directions, or the carrying capacity of the system was reduced and the population has had sufficient time to equilibrate with the new system (Gibbons and Munkittrick 1994). Examining the relative population sizes between reference and exposed sites can identify reduced carrying capacity. Unfortunately, CPUE data for site F-3 were not available. Identifying whether there are conflicting stressors is more difficult, experimentally and philosophically: if there is no detectable change in growth, survival or reproduction, has there been an impact?

The weight of evidence from the sentinel fish species data suggests that there is no readily apparent cause-effect relationship between metal concentrations and whole-organism or population responses. Additional study would help confirm whether there is, indeed, a difference in white sucker age structure; however, obtaining additional data on white sucker population characteristics is unlikely to change recommendations for clean up at the Deloro Mine Site. In other words, the sentinel fish data do not appear to justify a major incremental clean up effort at the Deloro Mine Site over and above what would be planned based upon meeting PWQOs.

References

Cohen, J. 1988. Statistical power analysis for the behavioural sciences. 2nd Ed. L. Erlbaum Assoc., Hillsdale, NJ. 567 p.

Dixon, D.G. and J.B. Sprague. 1981. Acclimation-induced changes in toxicity of arsenic and cyanide to rainbow trout, *Salmo gairdneri* Richardson. J. Fish. Biol. 18: 579-589.

Environment Canada. 1997. Fish survey expert working group final report. EEM Technical Management Committee. EEM/1997/6.

Faul, F. and E. Erdfelder. 1992. GPOWER. A priori, post-hoc and compromise power analyses for MS-DOS [Computer program]. Bonn, Germany. Bonn University, Dept. of Psychology.

Gagnon, M.M., J.J. Dodson, P.V. Hodson, G. Van Der Kraak and J.H. Carey. 1994. Seasonal effects of bleached kraft mill effluent on reproductive parameters of white sucker (*Catostomus commersoni*) populations of the St. Maurice River, Quebec, Canada. Can. J. Fish. Aquat. Sci. 51: 337-347.

Gibbons, W.N. and K.R. Munkittrick. 1994. A sentinel monitoring framework for identifying fish population responses to industrial discharges. J. Aquat. Ecosyst. Health 3:227-237.

Gibbons, W.N., K.R. Munkittrick and W.D. Taylor. 1998. Monitoring aquatic environments receiving industrial effluents using small fish species 2: Comparison between trout-perch (*Percopsis omiscoma*ycus) and white sucker (*Catostomus commersoni*) downstream of a pulp mill. Environ. Toxicol. Chem. 17:2238-2245.

Golder Associates Ltd. 2000. Final Report: Weyerhaeuser Canada Ltd., Grande Prairie Environmental Effects Monitoring Cycle 2. Prepared for Weyerhaeuser Canada Ltd., Grande Prairie, AB.

Grubbs, F.E. 1971. Procedures for detecting outlying observations in samples. Technometrics 11:1-22.

Hodson, P.V., M. McWhirter, K. Ralph, B. Gray, D. Thivierge, J.H. Carey, G. Van Der Kraak, D.M. Whittle and M. Levesque. 1992. Effects of bleached kraft mill effluent on fish in the St. Maurice River, Quebec. Environ. Toxicol. 11:1635-1652.

Kilgour, B.W., C.B. Portt and D.G. Dixon. 1999. Moira River impact study: detailed study design to determine the impact of the former Deloro Mine Site on the Moira River system. Prepared for the Ontario Ministry of Environment, Toronto, ON by Water Systems Analysts (WSA), Guelph, ON, C. Porrt and Associates, Guelph, ON and University of Waterloo, Waterloo, ON. 41 pp.

MacKay, W.C., G.R. Ash and H.J. Norris. (eds.). 1990. Fish ageing methods for Alberta. R.L. & L. Environmental Services Ltd. in assoc. with Alberta Fish and Wildl. Div. and Univ. of Alberta, Edmonton. 113 p.

McFarlane, G.A. and W.G. Franzin. 1978. Elevated heavy metals: a stress on a population of white suckers, *Catostomus commersoni*, in Hamell Lake, Saskatchewan. J. Fish. Res. Board. Can. 35:963-970.

McMaster, M.E., G.J. Van Der Kraak, C.B. Portt, K.R. Munkittrick, P.K. Sibley, I.R. Smith and D.G. Dixon. 1991. Changes in hepatic mixed-function oxygenase (MFO) activity, plasma steroid levels and age at maturity of white sucker (*Catostomus commersoni*) population exposed to bleached kraft pulp mill effluent. Aquat. Toxicol. 21:199-218.

Miller, P.A., K.R. Munkittrick and D.G. Dixon. 1992. Relationship between concentrations of copper and zinc in water, sediment, benthic invertebrates and tissues of white sucker (*Catostomus commersoni*) at metal-contaminated lakes. Can. J. Fish. Aquat. Sci. 49: 978-984.

Munkittrick, K.R. 1992. A review and evaluation of study design considerations for site-specifically assessing the health of fish populations. J. Aquat. Ecosyst. Health 1:283-293.

Munkittrick, K.R. and D.G. Dixon. 1988. Growth, fecundity and energy stores of white sucker (*Catostomus commersoni*) from lakes containing elevated levels of copper and zinc. Can. J. Fish. Aquat. Sci. 45: 1355-1365

Munkittrick and Dixon. 1989. Use of white sucker (*Catostomus commersoni*) populations to assess the health of aquatic ecosystems exposed to low-level contaminated stress. Can. J. Fish. Aquat. Sci. 46: 1455-1462.

Oladimeji. A.A., U. Qadri and A.S.W. de Freitas. 1984. Long-term effects of arsenic accumulation in rainbow trout. Bull. Environ. Contam. Toxicol. 32:732-741.

Paine, M.D. 1998. Volume II: CANMET/INTEMIN manual on statistical analysis of environmental data. Prepared for Natural Resources Canada, Canada Centre for Mineral and Energy Technology (CANMET), Ottawa, ON., by Paine, Ledge and Associates (PLA), North Vancouver, B.C. 228 pp.

Peterman, R.M. 1990. Statistical power analysis can improve fisheries research and management. Can. J. Fish. Aquat. Sci. 47: 2-15.

Post, G. 1987. Textbook of Fish Health, 2nd Edition. T.F.H. Publications Inc. Neptune City, NJ, USA. 288 pp.

Spehar, R.L., J.T. Fiandt, R.L. Anderson and D.L. DeFoe. 1980. Comparative toxicity of arsenic compounds and their accumulation in invertebrates and fish. Arch. Environm. Contam. Toxicol. 9:53-63.

Swanson. S.M. 1982. Levels and effects of radionuclides in aquatic fauna of the Beaverlodge area, Saskatchewan. Saskatchewan Research Council Report No. C-806-5-E-82. Prepared for Environment Canada, Environmental Protection Service, Regina, Saskatchewan.

Trippel, E.A. and H.H. Harvey. 1987. Reproductive responses of five white sucker (*Catostomus commersoni*) populations in relation to lake acidity. Can. J. Fish. Aquat. Sci. 44:1018-1023.

Wilkinson, L. 1990. SYSTAT: the system for statistics. SYSTAT Inc., Evanston, IL, USA.

3. ASSESSMENT OF RISKS TO HUMAN HEALTH DOWNSTREAM OF THE FORMER DELORO MINE SITE

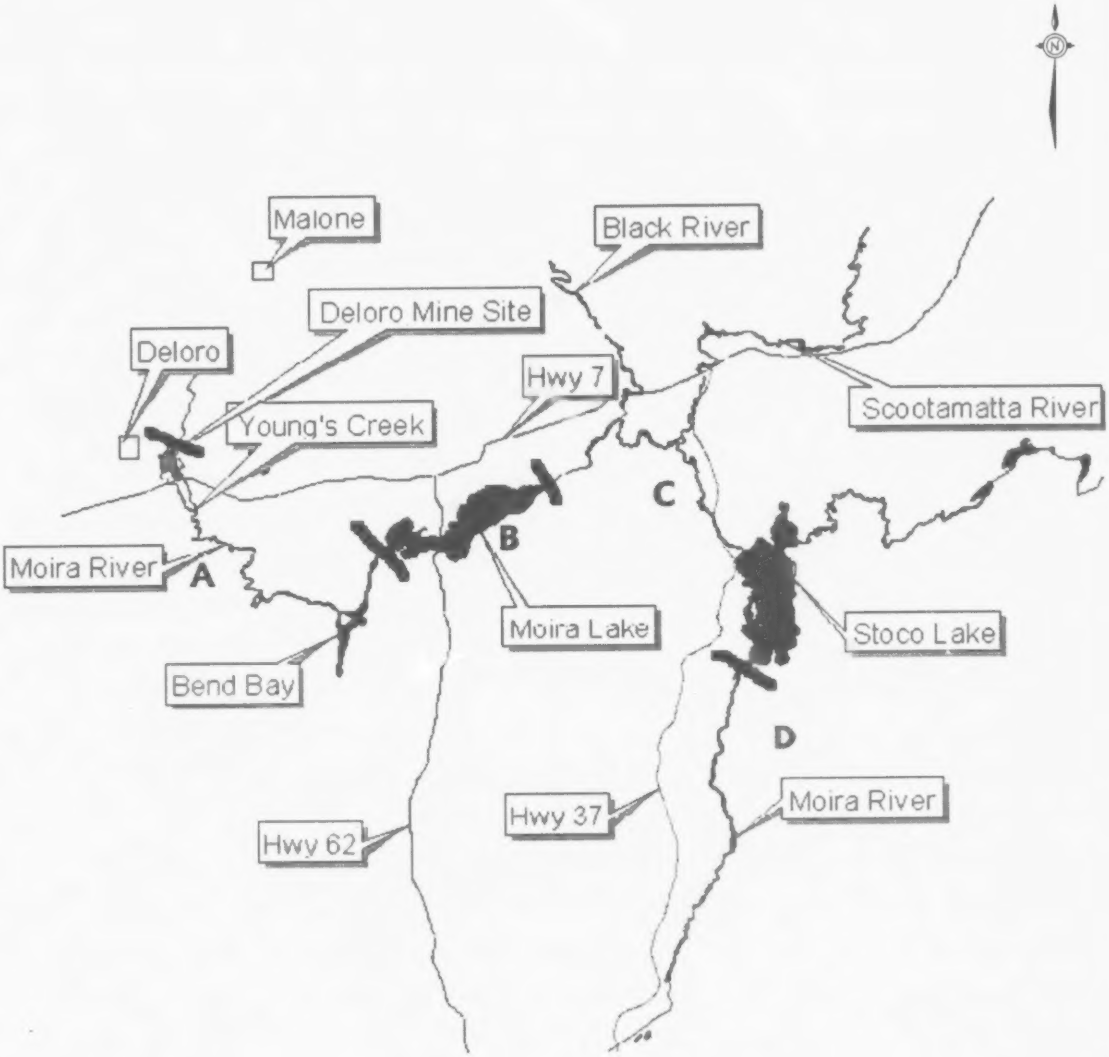
3.1 Introduction

The second component of the Phase II Moira River Study was to conduct a Preliminary Quantitative Risk Assessment (PQRA) of the Moira River system downstream of the Deloro Mine Site (see Figure 3.1-1). The objective of this PQRA was to determine whether there are potential current and future human health risks associated with substances released to the Moira River system from the Deloro Mine Site. The study is intended to guide future risk management strategies and remedial options. The study is not designed to examine potential health risks associated with historical exposures. The results of the PQRA were used to identify metals and exposure pathways that warranted additional study and/or risk management. This section presents the rationale, methodology and results of the PQRA.

In the PQRA, the Moira River system (or river system) includes the Moira River, Moira Lake and Stoco Lake.

As noted above, this is a screening assessment. In such an assessment, it is important to ensure that all relevant exposure scenarios are evaluated and that scenarios of concern are properly identified for further study. To ensure that these goals are met, the present assessment uses conservative data and assumptions with respect to chemical concentrations (highest and average concentrations are considered), exposure scenarios (use of the river for potable water, and recreational use of the river on a regular and frequent basis) and receptors (those most likely to have the highest exposure for the scenarios considered). Because of the use of this conservative approach, exposure estimates should be considered "worst case" estimates which are likely to overestimate true exposure levels and associated risks.

The worst case estimates produced by the PQRA added layers of safety to the assessment. Elimination of concern about particular metals or pathways of exposure was possible and defensible because of these layers of safety. Thus, if exposures were less than benchmark values (representing safe and acceptable exposures), it could be concluded with confidence that there was no risk to human health. Layers of safety are discussed further in Section 3.4.3.7.


Malone
Black River
Deloro Mine Site
Deloro
Hwy 7
Young's Creek
Scootamatta River
C
B
Moira River
A
Moira Lake
Stoco Lake
Bend Bay
D
Moira River
Hwy 37
Hwy 62
N

REFERENCE

BASE MAP PROVIDED BY GIS GOLDER MISSISSAUGA

SCHEMATIC ONLY
NOT TO SCALE

Golder Associates

PRELIMINARY QUALITATIVE RISK ASSESSMENT (PQRA) STUDY AREAS

DRAWN: TVS	APPROVED:	DATE:	16 Aug 2000
PROJECT: 991-1358.8200		FIGURE:	3.1-1

Revision No. 01

J:\1999\991-1358\8200\RISK ASSESSMENT.dwg

The primary objective of the PQRA is to determine the potential future health impacts associated with substances present in the river system and which are related to releases from the Deloro Mine Site.

3.1.1 Scope of Work

This PQRA was developed according to the risk assessment frameworks and methodologies detailed in the following documents:

- *"Guideline for Use at Contaminated Sites in Ontario, Revised February, 1997 (MOE 1996);*
- *"Guidance on Site Specific Risk Assessment (SSRA) for Use at Contaminated Sites in Ontario, May, 1996" (MOE 1996b);* and
- *Deloro Village Environmental Health Risk Study (CanTox 1999).*

As stated in the Terms of Reference for this study, the Preliminary Quantitative Risk Assessment (PQRA) was completed in a manner consistent with the environmental health risk assessment conducted for the Village of Deloro.

To support the completion of this screening level PQRA, a survey was conducted specifically to assess if residents were ingesting water from the Moira River system. This survey consisted of a questionnaire addressing:

- Location in the watershed;
- The use of the Moira River system as a source of drinking water;
- Year round or seasonal residency; and
- Other uses of water from the Moira River system (washing/bathing/gardening/ swimming/cooking).

The questionnaire did not address consumption patterns or number of occupants nor other issues relevant to a detailed exposure assessment. In July 1999, a total of 624 questionnaires were hand delivered by the Moira Lake Property Owners' Association or mailed to potential survey participants by the Ministry of the Environment to residents as far downstream as the outlet of Stoco Lake.

A total of 231 households responded and of these, eight households indicated that they use water from the river system for drinking purposes. Three of these respondents were located on Moira Lake, four were located downstream and an eighth respondent did not provide a location. Follow-up telephone contacts by the MOE revealed that one of the three respondents on Moira Lake stated that he had completed the questionnaire in error and was in fact consuming water from a drilled well. One respondent from Stoco Lake indicated that they were using a distillation system to treat the water prior to consumption. Nevertheless, the results of this survey indicate that some people may be using the Moira River system for drinking water purposes. The residents located downstream of the former Deloro Mine Site to the outlet of Moira Lake were subsequently reminded by a joint letter from the Hastings and Prince Edward Counties Health Unit and the Ministry of the Environment stating that the Ontario Drinking Water Objective for arsenic had been exceeded in the water of Moira Lake and that an alternative supply or treatment to remove arsenic should be considered (Appendix IX).

Although some residents may be using the river system as a source of drinking water, this water use pattern is clearly not indicative of the general water use pattern by most residents. Inclusion of this exposure pathway into the risk assessment will overestimate the potential health impacts to the vast majority of area residents that do not use the river system as a source of drinking water. Therefore, the PQRA considered both water use scenarios (i.e., water from the river system is used/not used as a source of drinking water) so as to provide a more reliable assessment of potential health impacts for residents of the study area.

3.1.2 Study Area Selection

The following four areas of the Moira River system downstream of the Deloro Mine Site were selected for the PQRA (Figure 3.1-1):

- Moira River from Deloro to Moira Lake (designated as Area "A");
- Moira Lake (designated as Area "B");
- Stoco Lake (designated as Area "C"); and
- Moira River downstream of Stoco Lake (designated as Area "D").

These areas were selected because they represent discrete sections of the river system that are likely to exhibit different environmental conditions based on their different physical characteristics, relative recreational use and proximity to the Deloro Mine Site. In addition to the four study areas, several reference locations were selected to provide data on the background concentrations of metals in areas not impacted by the Deloro Mine Site or other known point sources of metals (see Section 1.0). Some of the reference locations are part of the Moira River system upstream of the study areas and, as such, may contribute to the overall loading of metals into the system. Water and sediment samples were collected at all reference locations and analyzed for the same parameters as samples from the four study areas. Comparison of the concentrations detected in the reference locations to the study areas provides an indication of the impacts associated with the release of metals from the Deloro Mine Site.

3.1.3 Report Organization

Section 3.2 provides an overview of the approach that was employed for the PQRA. The problem formulation, which describes how humans may be exposed to chemicals in the river system, is described in Section 3.3. Section 3.4 describes the methodology, modelling results and the risk characterization. The conclusions and recommendations are given in Section 3.5.

3.2 Study Approach

This section describes the approach used for the PQRA to evaluate the potential impacts associated with the Moira River system. The PQRA is comprised of the following three steps:

Step 1) Data Compilation and Analysis

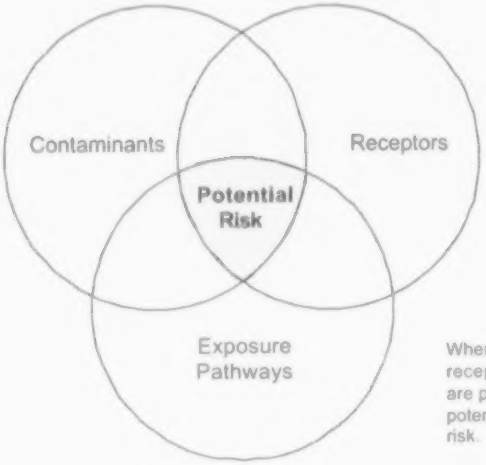
Chemical analysis data from this study and other studies of the Moira River system are discussed in Sections 2.1 and 2.2 with detailed data presentation in Appendices I and II. Fish tissue data were provided by the Ontario Sport Fish Contaminant Monitoring Program. The water, sediment and fish tissue chemistry data provided the input for the exposure analysis required for the PQRA.

Step 2) Problem Formulation

The problem formulation stage integrates basic information about potential risks into a conceptual model that describes how humans may be exposed to chemicals that represent a health risk. There are three prerequisites for a risk to exist (Figure 3.2-1):

- A chemical must be present at concentrations that may cause a deleterious health effect;
- A human receptor must be present; and
- An exposure pathway by which the human receptor can come into contact with the chemical must exist.

Figure 3.2-1
Environmental Risk Components



When contaminants, receptors, and pathways are present, there is a potential environmental risk.

However, the presence of all three components does not automatically indicate that an unacceptable risk or exposure is present, but only that it could exist.

Information about these three risk components is used to develop the problem formulation. The problem formulation focuses the risk assessment by eliminating chemicals, receptors and pathways that are not applicable or of little or no concern. This is done by examining chemical-specific parameters, characteristics of the study area (e.g., land use and geology) and the likely presence and activities of receptors (e.g., children and adult receptors). This information is used to develop a conceptual site model (CSM) which depicts the combinations of chemicals, receptors and connecting pathways that require further examination in the PQRA.

Step 3) Preliminary Quantitative Risk Assessment

The PQRA uses equations to estimate receptor exposure to substances of potential concern via the various pathways and exposure routes (inhalation, dermal absorption, and ingestion) identified in the CSM.

For non-carcinogenic substances, estimated exposures are compared to benchmark values that are expected to pose no risk, even among sensitive people exposed every day over a lifetime. For substances that are known to cause or probably cause cancer in people, an estimate of incremental lifetime cancer risk is developed.

3.3 Problem Formulation

3.3.1 Chemical Screening

The chemical screening process involves comparing the concentrations of chemicals measured in the water, sediment and fish to screening criteria. Screening criteria include guidelines or objectives set by regulatory agencies. These guidelines or objectives represent concentrations in water, sediments or fish that are protective of human health under all plausible exposure scenarios. When guidelines or objectives were not available, chemical concentrations in the study areas were compared to the corresponding concentration in water, sediment or fish samples from the reference locations. Chemicals detected at concentrations greater than the screening criteria or at concentrations greater than the reference locations were examined further in the PQRA. Chemicals detected at concentrations below or equal to the screening criteria are unlikely to represent a health risk and were not examined further.

3.3.1.1 Surface Water

Annual average and the ten-year average of the annual maximum metal concentrations in surface water (lakes and river) were compared to screening criteria. This approach involved comparing metal concentrations to the appropriate Ontario Drinking Water Objective (ODWO) (MOE 1999a). If an ODWO was not available, criteria from Table A (potable groundwater) of the MOE Cleanup Guideline were used (MOE 1999b). Both the ODWOs and Table A criteria are protective of human health, and consider exposure scenarios such as using the river water as potable drinking water and accidental ingestion during swimming. If exceedances of screening criteria only occurred at reference sites, the metal was not considered further. If exceedances occurred at both reference and Moira River system sites, but concentrations were higher at reference sites, the metal was not considered further. Substances that were detected at concentrations greater than the screening criteria were compared to the concentrations detected at the reference locations to determine if they are related to the Deloro Mine Site or if they are representative of normal background concentrations. Substances present in the river system at levels greater than the screening criteria and deemed to be related to releases from the Deloro Mine Site were evaluated further in the PQRA.

Water quality in the Moira River system fluctuates by season (i.e., water concentrations of metals are generally higher in late summer and early fall) (discussed in Section 2.1). Therefore, both annual mean and the ten-year average of the annual maximum detected concentrations were used to evaluate water quality in the chemical screening process. Use of the annual mean concentration provided a good indicator of overall water quality in the river system, whereas the ten-year average of the annual maximum concentration represented a reasonable "worst case" scenario.

Water quality data from 1990 to present was evaluated in this assessment. Data collected prior to 1990 were not evaluated since they were unlikely to be representative of existing environmental conditions.

Within the study areas and reference locations, concentrations of aluminum, iron and manganese occasionally exceeded the ODWOs. The screening criteria (ODWOs) for aluminum, iron and manganese are based on aesthetics or operational guidelines for water treatment facilities and are not health-based. Comparison of the concentrations detected in water to concentrations found in the reference locations and in surface waters throughout the Canadian Shield indicated that the levels of these metals detected in Study Area A did not appear elevated (CCME 1995). At the concentrations detected, these chemicals were not anticipated to represent a health risk. Therefore, these metals were not evaluated further in this assessment.

Cadmium, chromium and lead were also detected in a few study area samples at concentrations greater than the screening criteria. Comparison of the concentrations detected in the study areas to the reference locations reveals that the study area concentrations were not elevated relative to the reference sites. There are no data to indicate that these substances are associated with historical releases from the Deloro Mine Site. For instance, historical levels of lead have exceeded the PWQO at reference locations with greater magnitude than those found in the Moira River system and there have been only a few minor exceedances of the ODWO for this substance over the past ten years. These results indicate that the background geology in the area is likely the predominant source of lead to the Moira River system and not the Deloro Mine Site. The concentrations of lead, cadmium and chromium in the study area do not appear to be related to the Deloro Mine Site. Therefore, these substances in water were not considered further in this assessment.

There were also some study area samples with elevated concentrations of various metals that did not appear to be related to background. The concentrations detected were orders of magnitude higher than all other data points for these metals. These spurious results likely represent reporting or data transcription errors in the original data set and were considered outliers.

Since no radioactive substances (including uranium) were detected in water at concentrations greater than the screening criteria, the potential health risks associated with these substances were considered negligible. Therefore, these substances were not addressed further in this assessment.

Moira River from Deloro to Moira Lake (Study Area A)

Comparison of the annual mean and the ten year average of the annual maximum concentrations in water to the appropriate screening criteria revealed that the concentrations of arsenic, cobalt and nickel exceeded the screening criteria (see Tables 3.3-1 and 3.3-2). Therefore, the potential health risks associated with these substances in water were evaluated further in the PQRA (see Section 3.4). No other substances were detected at concentrations greater than the screening criteria.

Moira Lake (Study Area B)

Comparison of the annual mean and the ten year average of the annual maximum concentrations in water to the appropriate screening criteria revealed that arsenic concentrations exceeded the screening criteria (see Tables 3.3-3 and 3.3-4). Therefore, arsenic was evaluated further in the PQRA. No other substances were detected at concentrations greater than the screening criteria.

Stoco Lake (Study Area C)

Comparison of the annual mean and the ten year average of the annual maximum concentrations in water to the appropriate screening criteria revealed that maximum arsenic concentrations exceeded the screening criteria (see Tables 3.3-5 and 3.3-6). Therefore, the potential health risks associated with maximum arsenic concentrations in water in Study Area C were investigated further in the PQRA.

Moira River Downstream of Stoco Lake (Study Area D)

Comparison of the annual mean and the ten year average of the annual maximum concentrations in water to the appropriate screening criteria revealed that no substances were detected at concentrations greater than the screening criteria (see Tables 3.3-7 and 3.3-8). Therefore, the potential health risks associated with substances in water in Study Area D were not evaluated further in the PQRA.

Table 3.3-1
Area A Exceedances for Yearly Maximum Concentrations

Parameter	Year	ODWO[1] mg/L	Basis	Table A[2] mg/L	Reference	Site			
					Malone	D/S Deloro	Moira HWY-7	Young's Creek	Moira D/S Young's Creek
					W1	W2	DM7	DM1	DM8
ALUMINIUM, UNFILTERED TOTAL	1990	0.1	OG	NA	**0.19**	**0.11**			
ALUMINIUM, UNFILTERED TOTAL	1991	0.1	OG	NA	0.06	**0.125**			
ALUMINIUM, UNFILTERED TOTAL	1992	0.1	OG	NA	0.052	0.044			
ALUMINIUM, UNFILTERED TOTAL	1993	0.1	OG	NA	0.06	0.1			
ALUMINIUM, UNFILTERED TOTAL	1994	0.1	OG	NA	0.047	0.1			
ALUMINIUM, UNFILTERED TOTAL	1995	0.1	OG	NA	0.061	0.049			
ALUMINIUM, UNFILTERED TOTAL	1996	0.1	OG	NA	0.05	0.08			
ALUMINIUM, UNFILTERED TOTAL	1997	0.1	OG	NA		0.0392			
ALUMINIUM, UNFILTERED TOTAL	1998	0.1	OG	NA		0.0318			
ALUMINIUM, UNFILTERED TOTAL	1999	0.1	OG	NA					
ARSENIC, UNFILTERED TOTAL	1990	0.025	IMAC	0.025	0.015	**0.13**			
ARSENIC, UNFILTERED TOTAL	1991	0.025	IMAC	0.025	0.002	**0.39**			
ARSENIC, UNFILTERED TOTAL	1992	0.025	IMAC	0.025	0.004	**0.18**			
ARSENIC, UNFILTERED TOTAL	1993	0.025	IMAC	0.025	0.001	**0.092**	**0.113**	**0.523**	**0.121**
ARSENIC, UNFILTERED TOTAL	1994	0.025	IMAC	0.025	0.0016	**0.16**	**0.151**	**0.513**	**0.187**
ARSENIC, UNFILTERED TOTAL	1995	0.025	IMAC	0.025	0.001	0.023	**0.197**	**0.299**	**0.221**
ARSENIC, UNFILTERED TOTAL	1996	0.025	IMAC	0.025			**0.059**	**0.528**	**0.061**
ARSENIC, UNFILTERED TOTAL	1997	0.025	IMAC	0.025			**0.177**	**0.171**	**0.193**
ARSENIC, UNFILTERED TOTAL	1999	0.025	IMAC	0.025	0.0005	**0.27**			
COBALT, UNFILTERED TOTAL	1990	NA		0.1	0.0088	0.015			
COBALT, UNFILTERED TOTAL	1991	NA		0.1	0.0023	0.0185			
COBALT, UNFILTERED TOTAL	1992	NA		0.1	0.0006	0.0064			
COBALT, UNFILTERED TOTAL	1993	NA		0.1	0.0005	0.0041	0.018	0.057	0.005
COBALT, UNFILTERED TOTAL	1994	NA		0.1	0.0002	0.0028	0.017	**0.53**	0.043
COBALT, UNFILTERED TOTAL	1995	NA		0.1	0.0006	0.0024	0.005	0.009	0.01
COBALT, UNFILTERED TOTAL	1996	NA		0.1	0.0002	0.0016	0.004	**0.26**	0.021
COBALT, UNFILTERED TOTAL	1997	NA		0.1		0.00121	0.1	**0.33**	**0.34**
COBALT, UNFILTERED TOTAL	1998	NA		0.1		0.00407			
COBALT, UNFILTERED TOTAL	1999	NA		0.1	0.000397	0.00255			
IRON, FILTERED TOTAL	1996	0.3	AO	NA	0.22				
IRON, UNFILTERED TOTAL	1990	0.3	AO	NA	**0.32**	**0.33**			
IRON, UNFILTERED TOTAL	1991	0.3	AO	NA	**0.58**	**0.42**			
IRON, UNFILTERED TOTAL	1992	0.3	AO	NA	**0.32**	**0.32**			
IRON, UNFILTERED TOTAL	1993	0.3	AO	NA	**0.33**	**0.5**			
IRON, UNFILTERED TOTAL	1994	0.3	AO	NA	0.19	**0.43**			
IRON, UNFILTERED TOTAL	1995	0.3	AO	NA	**0.38**	**0.38**			
IRON, UNFILTERED TOTAL	1996	0.3	AO	NA	0.24	0.28			
IRON, UNFILTERED TOTAL	1997	0.3	AO	NA		0.135			
IRON, UNFILTERED TOTAL	1998	0.3	AO	NA		0.16			
IRON, UNFILTERED TOTAL	1999	0.3	AO	NA					
LEAD, UNFILTERED TOTAL	1990	0.01	MAC	0.01	0.005	0.005			
LEAD, UNFILTERED TOTAL	1991	0.01	MAC	0.01	0.005	0.005			
LEAD, UNFILTERED TOTAL	1992	0.01	MAC	0.01	0.005	0.005			
LEAD, UNFILTERED TOTAL	1993	0.01	MAC	0.01	0.005	0.005	**0.015**	**0.511**	**0.017**
LEAD, UNFILTERED TOTAL	1994	0.01	MAC	0.01	0.005	0.005	**0.023**	**0.016**	**0.022**
LEAD, UNFILTERED TOTAL	1995	0.01	MAC	0.01	0.005	0.005	0.007	0.006	0.007
LEAD, UNFILTERED TOTAL	1996	0.01	MAC	0.01	0.005	0.005	0.001	0.002	0.001
LEAD, UNFILTERED TOTAL	1997	0.01	MAC	0.01		0.00418	0.007	0.006	0.007
LEAD, UNFILTERED TOTAL	1998	0.01	MAC	0.01		0.0071			
LEAD, UNFILTERED TOTAL	1999	0.01	MAC	0.01	0.00323	0.00499			
MANGANESE, FILTERED TOTAL	1996	0.05	AO	NA	0.039				
MANGANESE, FILTERED TOTAL	1997	0.05	AO	NA					
MANGANESE, FILTERED TOTAL	1998	0.05	AO	NA		0.0375			
MANGANESE, UNFILTERED TOTAL	1994	0.05	AO	NA	0.026	0.022			
MANGANESE, UNFILTERED TOTAL	1995	0.05	AO	NA	0.048	**0.073**			
MANGANESE, UNFILTERED TOTAL	1996	0.05	AO	NA	0.039	0.04			
MANGANESE, UNFILTERED TOTAL	1997	0.05	AO	NA		0.0187			
MANGANESE, UNFILTERED TOTAL	1998	0.05	AO	NA		**0.129**			
MANGANESE, UNFILTERED TOTAL	1999	0.05	AO	NA					
NICKEL, UNFILTERED TOTAL	1990	NA		0.1	0.004	0.008			
NICKEL, UNFILTERED TOTAL	1991	NA		0.1	0.013	0.065			
NICKEL, UNFILTERED TOTAL	1992	NA		0.1	0.005	0.008			
NICKEL, UNFILTERED TOTAL	1993	NA		0.1	0.002	0.004	0.015	0.051	0.017
NICKEL, UNFILTERED TOTAL	1994	NA		0.1	0.0011	0.0027	0.021	0.042	0.018
NICKEL, UNFILTERED TOTAL	1995	NA		0.1	0.0009	0.0015	0.033	0.036	0.008
NICKEL, UNFILTERED TOTAL	1996	NA		0.1	0.0005	0.0015	0.012	0.088	0.01
NICKEL, UNFILTERED TOTAL	1997	NA		0.1		0.00072	0.04	**0.133**	**0.13**
NICKEL, UNFILTERED TOTAL	1998	NA		0.1		0.00351			
NICKEL, UNFILTERED TOTAL	1999	NA		0.1	0.00087	0.00773			

1 - Ontario Drinking Water Objectives, Ministry of Environment, 1994.

2 - Table A: Surface soil and groundwater remediation criteria for three land uses in a potable groundwater situation, Guideline for Use at Contaminated Sites in Ontario, Ministry of Environment and Energy, 1997.

AO - Aesthetic objective.
IMAC - Interim maximum acceptable concentration.
MAC - Maximum acceptable concentration.

NA - No value available.
OG - Operational Guideline.
BOLD - Exceeds ODWO. Where no ODWO is available, concentration exceeds Table A.

Table 3.3-2
Area A Exceedances for Average Concentrations

Parameter	Year	ODWO[1]	Basis	Table A[2]	Reference	Site A			
		mg/L		mg/L	Malone	D/S Deloro	Moira HWY-7	Young's Creek	Moira D/S Young's Creek
					W1	W2	DM7	DM1	DM8
ARSENIC, UNFILTERED TOTAL	1990	0.025	IMAC	0.025	0.002	**0.033**			
ARSENIC, UNFILTERED TOTAL	1991	0.025	IMAC	0.025	0.001	**0.084**			
ARSENIC, UNFILTERED TOTAL	1992	0.025	IMAC	0.025	0.002	**0.042**			
ARSENIC, UNFILTERED TOTAL	1993	0.025	IMAC	0.025	0.001	0.023	**0.036**	**0.201**	**0.047**
ARSENIC, UNFILTERED TOTAL	1994	0.025	IMAC	0.025	0.001	**0.036**	**0.034**	**0.195**	**0.047**
ARSENIC, UNFILTERED TOTAL	1995	0.025	IMAC	0.025	0.001	0.019	**0.062**	**0.156**	**0.071**
ARSENIC, UNFILTERED TOTAL	1996	0.025	IMAC	0.025			0.024	**0.195**	**0.030**
ARSENIC, UNFILTERED TOTAL	1997	0.025	IMAC	0.025			**0.034**	**0.096**	**0.063**
ARSENIC, UNFILTERED TOTAL	1999	0.025	IMAC	0.025	0.001	**0.083**			
COBALT, UNFILTERED TOTAL	1990	NA		0.1	0.002	0.004			
COBALT, UNFILTERED TOTAL	1901	NA		0.1	0.001	0.006			
COBALT, UNFILTERED TOTAL	1992	NA		0.1	0.001	0.002			
COBALT, UNFILTERED TOTAL	1993	NA		0.1	0.001	0.002	0.018	0.044	0.004
COBALT, UNFILTERED TOTAL	1994	NA		0.1	0.000	0.001	0.010	**0.183**	0.024
COBALT, UNFILTERED TOTAL	1995	NA		0.1	0.000	0.001	0.003	0.007	0.004
COBALT, UNFILTERED TOTAL	1996	NA		0.1	0.000	0.002	0.003	**0.103**	0.011
COBALT, UNFILTERED TOTAL	1987	NA		0.1		0.001	0.028	**0.139**	0.092
COBALT, UNFILTERED TOTAL	1998	NA		0.1		0.002			
COBALT, UNFILTERED TOTAL	1999	NA		0.1	0.000	0.002			
LEAD, UNFILTERED TOTAL	1990	0.01	MAC	0.01	0.005	0.005			
LEAD, UNFILTERED TOTAL	1991	0.01	MAC	0.01	0.005	0.005			
LEAD, UNFILTERED TOTAL	1992	0.01	MAC	0.01	0.005	0.005			
LEAD, UNFILTERED TOTAL	1993	0.01	MAC	0.01	0.005	0.005	0.007	**0.051**	0.005
LEAD, UNFILTERED TOTAL	1994	0.01	MAC	0.01	0.005	0.005	**0.012**	0.007	**0.010**
LEAD, UNFILTERED TOTAL	1995	0.01	MAC	0.01	0.005	0.005	0.003	0.004	0.003
LEAD, UNFILTERED TOTAL	1996	0.01	MAC	0.01	0.005	0.005	0.001	0.002	0.001
LEAD, UNFILTERED TOTAL	1997	0.01	MAC	0.01		0.004	0.005	0.003	0.004
LEAD, UNFILTERED TOTAL	1998	0.01	MAC	0.01		0.002			
LEAD, UNFILTERED TOTAL	1999	0.01	MAC	0.01	0.003	0.003			
MANGANESE, UNFILTERED TOTAL	1994	0.05	AO	NA	0.014	0.011			
MANGANESE, UNFILTERED TOTAL	1995	0.05	AO	NA	0.041	0.040			
MANGANESE, UNFILTERED TOTAL	1996	0.05	AO	NA	0.038	0.040			
MANGANESE, UNFILTERED TOTAL	1997	0.05	AO	NA		0.019			
MANGANESE, UNFILTERED TOTAL	1998	0.05	AO	NA		**0.058**			
MANGANESE, UNFILTERED TOTAL	1999	0.05	AO	NA					

1 - Ontario Drinking Water Objectives, Ministry of Environment, 1994

2 - Table A: Surface soil and groundwater remediation criteria for three land uses in a potable groundwater situation, Guideline for Use at Contaminated Sites in Ontario, Ministry of Environment and Energy, 1997

AO - Aesthetic objective

IMAC - Interim maximum acceptable concentration

MAC - Maximum acceptable concentration

NA - No value available

BOLD - Exceeds ODWO. Where no ODWO is available, concentration exceeds Table A.

Table 3.3-3
Area B Exceedances for Yearly Maximum Concentrations

Parameter	Year	ODWO[1]	Basis	Table A[2]	Reference	Site		
		mg/L		mg/L	Deer Cr	HWY 62 Bridge	Moira Lk Narrows	Moira Lk Outlet
					W4	W6	W7	W8
ALUMINIUM, UNFILTERED TOTAL	1990	0.1	OG	NA		0.062		
ALUMINIUM, UNFILTERED TOTAL	1991	0.1	OG	NA		0.03		
ALUMINIUM, UNFILTERED TOTAL	1992	0.1	OG	NA		0.099		
ALUMINIUM, UNFILTERED TOTAL	1993	0.1	OG	NA		0.034		
ALUMINIUM, UNFILTERED TOTAL	1994	0.1	OG	NA	**0.15**	0.031		
ALUMINIUM, UNFILTERED TOTAL	1995	0.1	OG	NA	**0.14**	0.041		
ALUMINIUM, UNFILTERED TOTAL	1996	0.1	OG	NA	0.05	0.04	0.04	
ALUMINIUM, UNFILTERED TOTAL	1997	0.1	OG	NA	0.0338		0.0436	
ALUMINIUM, UNFILTERED TOTAL	1998	0.1	OG	NA	0.0226		0.0188	
ALUMINIUM, UNFILTERED TOTAL	1999	0.1	OG	NA				
ARSENIC, UNFILTERED TOTAL	1990	0.025	IMAC	0.025	0.021	**0.085**		
ARSENIC, UNFILTERED TOTAL	1991	0.025	IMAC	0.025	0.016	**0.165**		
ARSENIC, UNFILTERED TOTAL	1992	0.025	IMAC	0.025	0.003	**0.097**		
ARSENIC, UNFILTERED TOTAL	1993	0.025	IMAC	0.025	0.002	**0.077**		
ARSENIC, UNFILTERED TOTAL	1994	0.025	IMAC	0.025	0.002	**0.079**		
ARSENIC, UNFILTERED TOTAL	1995	0.025	IMAC	0.025	0.001	0.015		
ARSENIC, UNFILTERED TOTAL	1996	0.025	IMAC	0.025				
ARSENIC, UNFILTERED TOTAL	1997	0.025	IMAC	0.025				
ARSENIC, UNFILTERED TOTAL	1999	0.025	IMAC	0.025	0.0015	**0.047**	**0.076**	0.024
CHROMIUM, UNFILTERED TOTAL	1990	0.05	MAC	0.05		0.0006		
CHROMIUM, UNFILTERED TOTAL	1991	0.05	MAC	0.05		0.001		
CHROMIUM, UNFILTERED TOTAL	1992	0.05	MAC	0.05	0.001	0.001		
CHROMIUM, UNFILTERED TOTAL	1993	0.05	MAC	0.05	0.0009	0.0014		
CHROMIUM, UNFILTERED TOTAL	1994	0.05	MAC	0.05	0.001	0.0005		
CHROMIUM, UNFILTERED TOTAL	1995	0.05	MAC	0.05	0.0011	0.0012		
CHROMIUM, UNFILTERED TOTAL	1996	0.05	MAC	0.05	0.0012	0.0008	0.0008	
CHROMIUM, UNFILTERED TOTAL	1997	0.05	MAC	0.05	6.71E-06		0.000678	
CHROMIUM, UNFILTERED TOTAL	1998	0.05	MAC	0.05	**0.259**[3]		0.000926	
CHROMIUM, UNFILTERED TOTAL	1999	0.05	MAC	0.05				
IRON, FILTERED TOTAL	1996	0.3	AO	NA	0.1		0.16	
IRON, UNFILTERED TOTAL	1990	0.3	AO	NA		0.2		
IRON, UNFILTERED TOTAL	1991	0.3	AO	NA		0.2		
IRON, UNFILTERED TOTAL	1992	0.3	AO	NA	0.29	0.19		
IRON, UNFILTERED TOTAL	1993	0.3	AO	NA	0.27	0.3		
IRON, UNFILTERED TOTAL	1994	0.3	AO	NA	**1**	0.25		
IRON, UNFILTERED TOTAL	1995	0.3	AO	NA	0.22	0.19		
IRON, UNFILTERED TOTAL	1996	0.3	AO	NA	0.12	0.22		
IRON, UNFILTERED TOTAL	1997	0.3	AO	NA	0.233		0.13	
IRON, UNFILTERED TOTAL	1998	0.3	AO	NA	0.185		0.128	
IRON, UNFILTERED TOTAL	1999	0.3	AO	NA				
MANGANESE, FILTERED TOTAL	1996	0.05	AO	NA	0.014		0.028	
MANGANESE, FILTERED TOTAL	1997	0.05	AO	NA				
MANGANESE, FILTERED TOTAL	1998	0.05	AO	NA				
MANGANESE, UNFILTERED TOTAL	1994	0.05	AO	NA	0.029	0.011		
MANGANESE, UNFILTERED TOTAL	1995	0.05	AO	NA	0.042	**0.053**		
MANGANESE, UNFILTERED TOTAL	1996	0.05	AO	NA	0.018	0.038		
MANGANESE, UNFILTERED TOTAL	1997	0.05	AO	NA	**0.0693**		0.018	
MANGANESE, UNFILTERED TOTAL	1998	0.05	AO	NA	**0.0661**		**0.061**	
MANGANESE, UNFILTERED TOTAL	1999	0.05	AO	NA				

1 - Ontario Drinking Water Objectives, Ministry of Environment, 1994

2 - Table A: Surface soil and groundwater remediation criteria for three land uses in a potable groundwater situation, Guideline for Use at Contaminated Sites in Ontario, Ministry of Environment and Energy, 1997

3 - Exceedance in reference area only; therefore not a contaminant of concern

AO - Aesthetic objective

IMAC - Interim maximum acceptable concentration

MAC - Maximum acceptable concentration

NA - No value available

OG - Operational Guideline

BOLD - Exceeds ODWO. Where no ODWO is available, concentration exceeds Table A.

Table 3.3-4
Area B Exceedances for Average Concentrations

Parameter	Year	ODWO[1]	Basis	Table A[2]	Reference	Site B		
		mg/L		mg/L	Deer Cr	HWY 62 Bridge	Moira Lk Narrows	Moira Lk Outlet
					W4	W6	W7	W8
ARSENIC, UNFILTERED TOTAL	1990	0.025	IMAC	0.025	0.002	**0.027**		
ARSENIC, UNFILTERED TOTAL	1991	0.025	IMAC	0.025	0.002	**0.036**		
ARSENIC, UNFILTERED TOTAL	1992	0.025	IMAC	0.025	0.001	**0.031**		
ARSENIC, UNFILTERED TOTAL	1993	0.025	IMAC	0.025	0.001	**0.025**		
ARSENIC, UNFILTERED TOTAL	1994	0.025	IMAC	0.025	0.001	**0.031**		
ARSENIC, UNFILTERED TOTAL	1995	0.025	IMAC	0.025	0.001	0.014		
ARSENIC, UNFILTERED TOTAL	1996	0.025	IMAC	0.025				
ARSENIC, UNFILTERED TOTAL	1997	0.025	IMAC	0.025				
ARSENIC, UNFILTERED TOTAL	1999	0.025	IMAC	0.025	0.001	0.025	**0.028**	0.016
CHROMIUM, UNFILTERED TOTAL	1990	0.05	MAC	0.05		0.001		
CHROMIUM, UNFILTERED TOTAL	1991	0.05	MAC	0.05		0.001		
CHROMIUM, UNFILTERED TOTAL	1992	0.05	MAC	0.05	0.001	0.001		
CHROMIUM, UNFILTERED TOTAL	1993	0.05	MAC	0.05	0.001	0.001		
CHROMIUM, UNFILTERED TOTAL	1994	0.05	MAC	0.05	0.001	0.000		
CHROMIUM, UNFILTERED TOTAL	1995	0.05	MAC	0.05	0.000	0.001		
CHROMIUM, UNFILTERED TOTAL	1996	0.05	MAC	0.05	0.001	0.001	0.001	
CHROMIUM, UNFILTERED TOTAL	1997	0.05	MAC	0.05	0.000		0.001	
CHROMIUM, UNFILTERED TOTAL	1998	0.05	MAC	0.05	**0.052**[3]		0.001	
CHROMIUM, UNFILTERED TOTAL	1999	0.05	MAC	0.05				
MANGANESE, UNFILTERED TOTAL	1994	0.05	AO	NA	0.0225	0.01045		
MANGANESE, UNFILTERED TOTAL	1995	0.05	AO	NA	0.0308	0.0366		
MANGANESE, UNFILTERED TOTAL	1996	0.05	AO	NA	0.016	0.033		
MANGANESE, UNFILTERED TOTAL	1997	0.05	AO	NA	**0.0693**		0.01735	
MANGANESE, UNFILTERED TOTAL	1998	0.05	AO	NA	0.025858		0.037475	
MANGANESE, UNFILTERED TOTAL	1999	0.05	AO	NA				

1 - Ontario Drinking Water Objectives, Ministry of Environment, 1994

2 - Table A: Surface soil and groundwater remediation criteria for three land uses in a potable groundwater situation, Guideline for Use at Contaminated Sites in Ontario, Ministry of Environment and Energy, 1997

3 - Exceedance in reference area only; therefore, not a substance of concern.

AO - Aesthetic objective

IMAC - Interim maximum acceptable concentration

MAC - Maximum acceptable concentration

NA - No value available

BOLD - Exceeds ODWO. Where no ODWO is available, concentration exceeds Table A.

Table 3.3-5
Area C Exceedances for Yearly Maximum Concentrations

Parameter	YearO	DWO[1]	Basis	Table A[2]	Reference				Site		
		mg/L		mg/L	Black R	Skootamatta R	Sulphide Cr	Clare R	Stoco Lk Inlet	Stoco Lk Outlet	Stoco BRG
					W9	W10	W12	W13	W11	W15	W17
ALUMINIUM, UNFILTERED TOTAL	1990	0.1	OG	NA							
ALUMINIUM, UNFILTERED TOTAL	1991	0.1	OG	NA							
ALUMINIUM, UNFILTERED TOTAL	1992	0.1	OG	NA							
ALUMINIUM, UNFILTERED TOTAL	1993	0.1	OG	NA							
ALUMINIUM, UNFILTERED TOTAL	1994	0.1	OG	NA	0.045	0.053	0.079	0.066	0.04	0.037	0.029
ALUMINIUM, UNFILTERED TOTAL	1995	0.1	OG	NA	0.087	0.095	**0.13**	0.081	0.097	0.069	0.06
ALUMINIUM, UNFILTERED TOTAL	1996	0.1	OG	NA	0.1	**0.16**	**0.11**	0.08	0.1	0.08	0.07
ALUMINIUM, UNFILTERED TOTAL	1997	0.1	OG	NA	0.0619	0.0682	**0.12**	0.0439	0.0493	0.0467	0.0548
ALUMINIUM, UNFILTERED TOTAL	1998	0.1	OG	NA	0.0513	0.0546	0.0852	0.0368	0.0424	0.0466	0.0349
ALUMINIUM, UNFILTERED TOTAL	1999	0.1	OG	NA						0.0337	
ARSENIC, UNFILTERED TOTAL	1990	0.025	IMAC	0.025	0.001	0.001	0.002	0.002	0.008	0.019	0.016
ARSENIC, UNFILTERED TOTAL	1991	0.025	IMAC	0.025	0.001	0.002	0.007	0.003	0.011	0.018	0.016
ARSENIC, UNFILTERED TOTAL	1992	0.025	IMAC	0.025	0.001	0.001	0.009	0.002	0.024	**0.026**	**0.027**
ARSENIC, UNFILTERED TOTAL	1993	0.025	IMAC	0.025	0.001	0.001	0.001	0.005	0.009	**0.026**	**0.028**
ARSENIC, UNFILTERED TOTAL	1994	0.025	IMAC	0.025	0.001	0.001	0.001	0.002	0.009	0.012	0.012
ARSENIC, UNFILTERED TOTAL	1995	0.025	IMAC	0.025	0.001	0.001	0.001	0.001	0.0052	0.0042	0.0039
ARSENIC, UNFILTERED TOTAL	1996	0.025	IMAC	0.025							
ARSENIC, UNFILTERED TOTAL	1997	0.025	IMAC	0.025							
ARSENIC, UNFILTERED TOTAL	1999	0.025	IMAC	0.025	0.0005	0.0005		0.001	0.018	0.018	0.018
CADMIUM, UNFILTERED TOTAL	1990	0.005	MAC	0.005				0.0002			
CADMIUM, UNFILTERED TOTAL	1991	0.005	MAC	0.005				0.0012			
CADMIUM, UNFILTERED TOTAL	1992	0.005	MAC	0.005	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
CADMIUM, UNFILTERED TOTAL	1993	0.005	MAC	0.005	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002
CADMIUM, UNFILTERED TOTAL	1994	0.005	MAC	0.005	0.0002	0.0003	0.0003	0.0004	0.0003	0.0003	0.0003
CADMIUM, UNFILTERED TOTAL	1995	0.005	MAC	0.005	0.0002	0.0001	0.0015	0.0001	0.0003	0.0002	0.0001
CADMIUM, UNFILTERED TOTAL	1996	0.005	MAC	0.005	0.0001	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001
CADMIUM, UNFILTERED TOTAL	1997	0.005	MAC	0.005	0.000392	0.000239	0.000166	0.000392	0.0000376	0.000261	0.000365
CADMIUM, UNFILTERED TOTAL	1998	0.005	MAC	0.005	0.000414	0.00031	**0.368**[3]	0.00025	0.000229	**0.246**[3]	0.00017
CADMIUM, UNFILTERED TOTAL	1999	0.005	MAC	0.005						0.0000616	
IRON, FILTERED TOTAL	1996	0.3	AO	NA	**0.36**	**0.46**	**0.38**	0.2	0.3	0.3	0.3
IRON, UNFILTERED TOTAL	1990	0.3	AO	NA				0.25			
IRON, UNFILTERED TOTAL	1991	0.3	AO	NA				**0.54**			
IRON, UNFILTERED TOTAL	1992	0.3	AO	NA	**0.76**	**0.8**	**0.8**	**0.34**	**0.55**	**0.56**	**0.43**
IRON, UNFILTERED TOTAL	1993	0.3	AO	NA	**0.76**	**0.84**	**0.88**	**0.5**	**0.63**	**0.55**	**0.51**
IRON, UNFILTERED TOTAL	1994	0.3	AO	NA	**0.79**	**0.84**	**1.3**	**0.41**	**0.54**	**0.54**	**0.46**
IRON, UNFILTERED TOTAL	1995	0.3	AO	NA	**0.68**	**0.57**	**1.5**	0.29	**0.43**	**0.35**	**0.31**
IRON, UNFILTERED TOTAL	1996	0.3	AO	NA	**0.4**	**0.48**	**0.38**	0.28	**0.54**	**0.36**	**0.34**
IRON, UNFILTERED TOTAL	1997	0.3	AO	NA	**0.356**	**0.351**	**0.831**	0.188	0.245	0.196	0.201
IRON, UNFILTERED TOTAL	1998	0.3	AO	NA	**0.361**	**0.304**	**0.838**	0.216	0.258	0.26	0.222
IRON, UNFILTERED TOTAL	1999	0.3	AO	NA							
MANGANESE, FILTERED TOTAL	1996	0.05	AO	NA	0.048	0.046	0.044	0.029	0.046	0.048	0.05
MANGANESE, FILTERED TOTAL	1997	0.05	AO	NA						0.0269	
MANGANESE, FILTERED TOTAL	1998	0.05	AO	NA			**0.258**	**0.0563**			**0.124**
MANGANESE, UNFILTERED TOTAL	1994	0.05	AO	NA	0.023	0.024	0.05	0.023	0.024	0.024	0.03
MANGANESE, UNFILTERED TOTAL	1995	0.05	AO	NA	**0.073**	**0.064**	**0.48**	**0.085**	**0.069**	**0.12**	0.039
MANGANESE, UNFILTERED TOTAL	1996	0.05	AO	NA	0.038	0.046	0.044	0.036	0.046	**0.057**	**0.068**
MANGANESE, UNFILTERED TOTAL	1997	0.05	AO	NA	**0.063**	**0.0597**	**0.2**	**0.0566**	**0.0542**	0.0429	0.0404
MANGANESE, UNFILTERED TOTAL	1998	0.05	AO	NA	**0.0611**	**0.0525**	**0.527**	**0.0775**	**0.0577**	**0.16**	**0.169**
MANGANESE, UNFILTERED TOTAL	1999	0.05	AO	NA							

1 - Ontario Drinking Water Objectives, Ministry of Environment, 1994

2 - Table A: Surface soil and groundwater remediation criteria for three land uses in a potable groundwater situation, Guideline for Use at Contaminated Sites in Ontario, Ministry of Environment and Energy, 1997

3- Exceedance at both reference and downstream Moira site, and downstream Moira site concentration is less than reference; therefore, not a substance of concern.

AO - Aesthetic objective

IMAC - Interim maximum acceptable concentration

MAC - Maximum acceptable concentration

NA - No value available

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BOLD - Exceeds ODWO. Where no ODWO is available, concentration exceeds Table A.

Table 3.3-6
Area C Exceedances for Average Concentrations

Parameter	Year	ODWO[1]	Basis	Table A[2]	Reference				Site C		
		mg/L		mg/L	Black R	Skootamatta R	Sulphide Cr	Clare R	Stoco Lk Inlet	Stoco Lk Outlet	Stoco BRG
					W9	W10	W12	W13	W11	W15	W17
ALUMINIUM, UNFILTERED TOTAL	1990	0.1	OG	NA							
ALUMINIUM, UNFILTERED TOTAL	1991	0.1	OG	NA							
ALUMINIUM, UNFILTERED TOTAL	1992	0.1	OG	NA							
ALUMINIUM, UNFILTERED TOTAL	1993	0.1	OG	NA							
ALUMINIUM, UNFILTERED TOTAL	1994	0.1	OG	NA	0.038	0.046	0.040	0.033	0.032	0.019	0.015
ALUMINIUM, UNFILTERED TOTAL	1995	0.1	OG	NA	0.064	0.080	0.099	0.056	0.063	0.047	0.042
ALUMINIUM, UNFILTERED TOTAL	1996	0.1	OG	NA	0.090	**0.140**	0.100	0.060	0.087	0.073	0.070
ALUMINIUM, UNFILTERED TOTAL	1997	0.1	OG	NA	0.040	0.053	0.092	0.034	0.039	0.036	0.039
ALUMINIUM, UNFILTERED TOTAL	1998	0.1	OG	NA	0.023	0.025	0.045	0.027	0.024	0.023	0.016
ALUMINIUM, UNFILTERED TOTAL	1999	0.1	OG	NA						0.034	
CADMIUM, UNFILTERED TOTAL	1990	0.005	MAC	0.005				0.000			
CADMIUM, UNFILTERED TOTAL	1991	0.005	MAC	0.005				0.000			
CADMIUM, UNFILTERED TOTAL	1992	0.005	MAC	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CADMIUM, UNFILTERED TOTAL	1993	0.005	MAC	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CADMIUM, UNFILTERED TOTAL	1994	0.005	MAC	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CADMIUM, UNFILTERED TOTAL	1995	0.005	MAC	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CADMIUM, UNFILTERED TOTAL	1996	0.005	MAC	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CADMIUM, UNFILTERED TOTAL	1997	0.005	MAC	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CADMIUM, UNFILTERED TOTAL	1998	0.005	MAC	0.005	0.000	0.000	**0.061**[3]	0.000	0.000	**0.049**[3]	0.000
CADMIUM, UNFILTERED TOTAL	1999	0.005	MAC	0.005						0.000	
IRON, UNFILTERED TOTAL	1990	0.3	AO	NA				0.175			
IRON, UNFILTERED TOTAL	1991	0.3	AO	NA				0.213			
IRON, UNFILTERED TOTAL	1992	0.3	AO	NA	**0.363**	**0.405**	**0.577**	0.172	0.262	0.222	0.194
IRON, UNFILTERED TOTAL	1993	0.3	AO	NA	**0.423**	**0.386**	**0.567**	0.228	0.296	0.192	0.182
IRON, UNFILTERED TOTAL	1994	0.3	AO	NA							
IRON, UNFILTERED TOTAL	1994	0.3	AO	NA	**0.456**	**0.482**	**0.779**	0.212	**0.322**	0.250	0.219
IRON, UNFILTERED TOTAL	1995	0.3	AO	NA	**0.492**	**0.438**	**0.968**	0.196	**0.360**	0.270	0.236
IRON, UNFILTERED TOTAL	1996	0.3	AO	NA	**0.400**	**0.470**	**0.360**	0.240	**0.420**	**0.330**	**0.320**
IRON, UNFILTERED TOTAL	1997	0.3	AO	NA	0.291	0.271	**0.654**	0.174	0.217	0.191	0.189
IRON, UNFILTERED TOTAL	1998	0.3	AO	NA	0.217	0.261	**0.577**	0.161	0.174	0.126	0.128
IRON, UNFILTERED TOTAL	1999	0.3	AO	NA							
MANGANESE, UNFILTERED TOTAL	1994	0.05	AO	NA	0.023	0.023	0.027	0.012	0.023	0.012	0.016
MANGANESE, UNFILTERED TOTAL	1995	0.05	AO	NA	0.038	0.049	**0.177**	**0.055**	0.048	0.048	0.026
MANGANESE, UNFILTERED TOTAL	1996	0.05	AO	NA	0.038	0.046	0.044	0.033	0.043	**0.053**	**0.059**
MANGANESE, UNFILTERED TOTAL	1997	0.05	AO	NA	0.046	0.037	**0.140**	0.036	0.041	0.043	0.034
MANGANESE, UNFILTERED TOTAL	1998	0.05	AO	NA	**0.051**	0.038	**0.188**	0.034	0.035	**0.074**	**0.092**
MANGANESE, UNFILTERED TOTAL	1999	0.05	AO	NA							

1 - Ontario Drinking Water Objectives, Ministry of Environment, 1994

2 - Table A: Surface soil and groundwater remediation criteria for three land uses in a potable groundwater situation, Guideline for Use at Contaminated Sites in Ontario, Ministry of Environment and Energy, 1997

3- Exceedance at both reference and downstream Moira site, and downstream Moira site concentration is less than references; therefore, not a substance of concern.

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MAC - Maximum acceptable concentration

NA - No value available

BOLD - Exceeds ODWO. Where no ODWO is available, concentration exceeds Table A.

Table 3.3-7
Area D Exceedances for Yearly Maximum Concentrations

Parameter	Year	ODWO[1]	Basis	Table A[2]	Reference		Site		
		mg/L		mg/L	Palliser Cr Quinte	Palliser Cr Foxborough	Cannifton	Belleville HWY-2	Belleville Victoria St
					W18	W19	W20	W23	W24
ALUMINIUM, UNFILTERED TOTAL	1990	0.1	OG	NA					
ALUMINIUM, UNFILTERED TOTAL	1991	0.1	OG	NA					
ALUMINIUM, UNFILTERED TOTAL	1992	0.1	OG	NA					
ALUMINIUM, UNFILTERED TOTAL	1993	0.1	OG	NA					0.032
ALUMINIUM, UNFILTERED TOTAL	1994	0.1	OG	NA			0.020	0.06	**0.11**
ALUMINIUM, UNFILTERED TOTAL	1995	0.1	OG	NA			**0.22**	0.082	0.042
ALUMINIUM, UNFILTERED TOTAL	1996	0.1	OG	NA			0.08	0.1	
ALUMINIUM, UNFILTERED TOTAL	1997	0.1	OG	NA			0.0449	0.0452	0.0361
ALUMINIUM, UNFILTERED TOTAL	1998	0.1	OG	NA	0.0194	**0.113**	0.0332	0.0314	0.0335
ALUMINIUM, UNFILTERED TOTAL	1999	0.1	OG	NA	0.0146	0.0787			
CHROMIUM, UNFILTERED TOTAL	1990	0.05	MAC	0.05			0.0017	0.0015	
CHROMIUM, UNFILTERED TOTAL	1991	0.05	MAC	0.05			0.001	0.009	
CHROMIUM, UNFILTERED TOTAL	1992	0.05	MAC	0.05			0.001	0.0005	
CHROMIUM, UNFILTERED TOTAL	1993	0.05	MAC	0.05			0.0007	**12**[3]	0.0005
CHROMIUM, UNFILTERED TOTAL	1994	0.05	MAC	0.05			0.0009	0.0011	0.0006
CHROMIUM, UNFILTERED TOTAL	1995	0.05	MAC	0.05			0.0012	0.001	0.001
CHROMIUM, UNFILTERED TOTAL	1996	0.05	MAC	0.05			0.0006	0.0004	
CHROMIUM, UNFILTERED TOTAL	1997	0.05	MAC	0.05			0.000071	0.000582	0.00263
CHROMIUM, UNFILTERED TOTAL	1998	0.05	MAC	0.05	0.00478	0.000275	**0.163**[3]	0.00075	0.000729
CHROMIUM, UNFILTERED TOTAL	1999	0.05	MAC	0.05	0.000783	0.000616			
IRON, FILTERED TOTAL	1996	0.3	AO	NA			**0.32**	**0.32**	
IRON, UNFILTERED TOTAL	1990	0.3	AO	NA			**0.31**	**0.32**	
IRON, UNFILTERED TOTAL	1991	0.3	AO	NA			0.3	**0.31**	
IRON, UNFILTERED TOTAL	1992	0.3	AO	NA			**0.33**	0.28	
IRON, UNFILTERED TOTAL	1993	0.3	AO	NA			0.092	**0.37**	0.16
IRON, UNFILTERED TOTAL	1994	0.3	AO	NA			**0.96**	**1.6**	**0.4**
IRON, UNFILTERED TOTAL	1995	0.3	AO	NA			**0.67**	0.28	**0.31**
IRON, UNFILTERED TOTAL	1996	0.3	AO	NA			**0.36**	**0.42**	
IRON, UNFILTERED TOTAL	1997	0.3	AO	NA			0.17	0.168	0.23
IRON, UNFILTERED TOTAL	1998	0.3	AO	NA	0.0283	0.263	0.195	0.183	0.199
IRON, UNFILTERED TOTAL	1999	0.3	AO	NA	0.0248	**0.323**			
LEAD, UNFILTERED TOTAL	1990	0.01	MAC	0.01			0.005	0.005	
LEAD, UNFILTERED TOTAL	1991	0.01	MAC	0.01			0.005	0.005	
LEAD, UNFILTERED TOTAL	1992	0.01	MAC	0.01			0.005	0.005	
LEAD, UNFILTERED TOTAL	1993	0.01	MAC	0.01			0.005	0.005	0.005
LEAD, UNFILTERED TOTAL	1994	0.01	MAC	0.01			0.006	0.006	0.005
LEAD, UNFILTERED TOTAL	1995	0.01	MAC	0.01			0.0058	0.005	0.005
LEAD, UNFILTERED TOTAL	1996	0.01	MAC	0.01			0.005	0.005	
LEAD, UNFILTERED TOTAL	1997	0.01	MAC	0.01			0.00445	0.00787	**0.0138**
LEAD, UNFILTERED TOTAL	1998	0.01	MAC	0.01	0.00534	0.000416	0.00413	0.00654	0.00899
LEAD, UNFILTERED TOTAL	1999	0.01	MAC	0.01	0.00909	0.0035	0.00399	0.00399	0.00512
MANGANESE, FILTERED TOTAL	1996	0.05	AO	NA			**0.051**	**0.052**	
MANGANESE, FILTERED TOTAL	1997	0.05	AO	NA					
MANGANESE, FILTERED TOTAL	1998	0.05	AO	NA				**0.0527**	
MANGANESE, UNFILTERED TOTAL	1994	0.05	AO	NA			0.031	0.032	0.026
MANGANESE, UNFILTERED TOTAL	1995	0.05	AO	NA			**0.23**	**0.056**	**0.088**
MANGANESE, UNFILTERED TOTAL	1996	0.05	AO	NA			**0.065**	**0.08**	
MANGANESE, UNFILTERED TOTAL	1997	0.05	AO	NA			**0.0539**	**0.0528**	**0.0654**
MANGANESE, UNFILTERED TOTAL	1998	0.05	AO	NA	0.0116	**0.0741**	0.0495	0.0404	**0.342**
MANGANESE, UNFILTERED TOTAL	1999	0.05	AO	NA	0.0158	**0.0892**			

1 - Ontario Drinking Water Objectives, Ministry of Environment, 1994

2 - Table A: Surface soil and groundwater remediation criteria for three land uses in a potable groundwater situation, Guideline for Use at Contaminated Sites in Ontario, Ministry of Environment and Energy, 1997

3- Outlier; data entry or laboratory error

AO - Aesthetic objective

IMAC - Interim maximum acceptable concentration

MAC - Maximum acceptable concentration

NA - No value available
OG - Operational Guideline
BOLD - Exceeds ODWO. Where no ODWO is available, concentration exceeds Table A.

Table 3.3-8
Area D Exceedances for Average Concentrations

Parameter	Year	ODWO[1]	Basis	Table A[2]	Reference		Site D		
		mg/L		mg/L	Palliser Cr Quinte	Palliser Cr Foxborough	Cannifton	Belleville HWY-2	Belleville Victoria St
					W18	W19	W20	W23	W24
ALUMINIUM, UNFILTERED TOTAL	1990	0.1	OG	NA					
ALUMINIUM, UNFILTERED TOTAL	1991	0.1	OG	NA					
ALUMINIUM, UNFILTERED TOTAL	1992	0.1	OG	NA					
ALUMINIUM, UNFILTERED TOTAL	1993	0.1	OG	NA					0.021
ALUMINIUM, UNFILTERED TOTAL	1994	0.1	OG	NA			0.029	0.031	0.039
ALUMINIUM, UNFILTERED TOTAL	1995	0.1	OG	NA			**0.102**	0.046	0.040
ALUMINIUM, UNFILTERED TOTAL	1996	0.1	OG	NA			0.080	0.087	
ALUMINIUM, UNFILTERED TOTAL	1997	0.1	OG	NA			0.036	0.035	0.025
ALUMINIUM, UNFILTERED TOTAL	1998	0.1	OG	NA	0.015	**0.101**	0.015	0.013	0.019
ALUMINIUM, UNFILTERED TOTAL	1999	0.1	OG	NA	0.013	0.069			
CHROMIUM, UNFILTERED TOTAL	1990	0.05	MAC	0.05			0.001	0.001	
CHROMIUM, UNFILTERED TOTAL	1991	0.05	MAC	0.05			0.001	0.001	
CHROMIUM, UNFILTERED TOTAL	1992	0.05	MAC	0.05			0.001	0.001	
CHROMIUM, UNFILTERED TOTAL	1993	0.05	MAC	0.05			0.001	**1.091**[3]	0.001
CHROMIUM, UNFILTERED TOTAL	1994	0.05	MAC	0.05			0.000	0.001	0.000
CHROMIUM, UNFILTERED TOTAL	1995	0.05	MAC	0.05			0.001	0.001	0.001
CHROMIUM, UNFILTERED TOTAL	1996	0.05	MAC	0.05			0.000	0.000	
CHROMIUM, UNFILTERED TOTAL	1997	0.05	MAC	0.05			0.000	0.000	0.001
CHROMIUM, UNFILTERED TOTAL	1998	0.05	MAC	0.05	0.003	0.000	0.027	0.000	0.001
CHROMIUM, UNFILTERED TOTAL	1999	0.05	MAC	0.05	0.000	0.000			
IRON, UNFILTERED TOTAL	1990	0.3	AO	NA			0.137	0.140	
IRON, UNFILTERED TOTAL	1991	0.3	AO	NA			0.160	0.105	
IRON, UNFILTERED TOTAL	1992	0.3	AO	NA			0.228	0.157	
IRON, UNFILTERED TOTAL	1993	0.3	AO	NA			0.068	0.129	0.120
IRON, UNFILTERED TOTAL	1994	0.3	AO	NA			0.087	0.001	
IRON, UNFILTERED TOTAL	1994	0.3	AO	NA			**0.503**	**0.407**	0.266
IRON, UNFILTERED TOTAL	1995	0.3	AO	NA			**0.398**	0.208	0.300
IRON, UNFILTERED TOTAL	1996	0.3	AO	NA			**0.340**	**0.370**	
IRON, UNFILTERED TOTAL	1997	0.3	AO	NA			0.156	0.152	0.137
IRON, UNFILTERED TOTAL	1998	0.3	AO	NA	0.023	0.222	0.074	0.069	0.162
IRON, UNFILTERED TOTAL	1999	0.3	AO	NA	0.023	0.230			
MANGANESE, UNFILTERED TOTAL	1994	0.05	AO	NA			0.031	0.020	0.025
MANGANESE, UNFILTERED TOTAL	1995	0.05	AO	NA			**0.106**	0.032	**0.065**
MANGANESE, UNFILTERED TOTAL	1996	0.05	AO	NA			**0.058**	**0.066**	
MANGANESE, UNFILTERED TOTAL	1997	0.05	AO	NA			0.036	0.036	0.033
MANGANESE, UNFILTERED TOTAL	1998	0.05	AO	NA	0.011	0.049	0.034	0.027	**0.095**
MANGANESE, UNFILTERED TOTAL	1999	0.05	AO	NA	0.013	**0.064**			

1 - Ontario Drinking Water Objectives, Ministry of Environment, 1994

2 - Table A: Surface soil and groundwater remediation criteria for three land uses in a potable groundwater situation, Guideline for Use at Contaminated Sites in Ontario, Ministry of Environment and Energy, 1997

3- Outlier; data entry or laboratory error

AO - Aesthetic objective

IMAC - Interim maximum acceptable concentration

MAC - Maximum acceptable concentration

NA - No value available

BOLD - Exceeds ODWO. Where no ODWO is available, concentration exceeds Table A.

Summary of Substances of Potential Concern in Surface Water

The results of the chemical screening process indicated that arsenic, cobalt and nickel concentrations were present in water at concentrations greater than human health-based screening criteria, and required further evaluation in the PQRA, as summarized in Table 3.3-9.

Table 3.3-9
Substances in Water Which Require Further Assessment in the PQRA

Substance	Area A	Area B	Area C	Area D
Arsenic	✓	✓	✓*	
Cobalt	✓			
Nickel	✓*			

✓ substance requires further evaluation in the PQRA.
✓* maximum concentrations only.

3.3.1.2 Sediment

It is possible that area residents may come into contact with sediments from the Moira River system during recreational activities such as swimming. However, there are no sediment criteria that consider the potential human health impacts associated with exposure to substances in sediments. In the absence of appropriate health-based screening criteria, sediment concentrations of arsenic, cadmium, cobalt, lead, nickel, and chromium from each study area were compared to concentrations in the reference locations. Any substances with statistically significant ($p < 0.05$) elevated concentrations relative to the reference locations were identified and evaluated further in the preliminary quantitative risk assessment (PQRA). For the statistical analysis, deep water and near shore (i.e., shallow water) sediment samples from each study area and reference areas were used. However, the exposure models considered only the near shore (i.e., sediment samples taken from a water depth of 1 meter or less) sediment samples since a child aged 5 - 11 is unlikely to come into contact with sediments present at greater depths. Data from the reference locations are provided in Table 3.3-10.

Table 3.3-10
Reference Sediment Samples (µg/g dry weight), Sampled April 1, 1999

Parameter	MR-1	MR-2	MR-3	BR-1	CL-1	CL-2	CL-3	CL-4	CL-5	CL-6	CL-7	CL-8
Arsenic	1.4	2.9	14	4.7	0.8	1.7	1.7	0.9	0.6	0.6	0.6	3.8
Cadmium	0.3	0.2	0.7	0.4	0.2	0.5	0.2	0.2	0.2	0.2	0.2	0.8
Chromium	18	27	24	18	1	8	7	3	1	4	4	15
Cobalt	5.6	7.5	9	7.1	0.5	2.9	2.2	1	0.7	1.2	0.8	6.3
Lead	3	5	8	4	4	23	11	6	2	2	2	49
Nickel	9.2	15	13	8.5	1.3	5.9	3.3	1.7	0.9	1.6	1.4	11
Parameter	**RL-1**	**RL-2**	**RL-3**	**RL-4**	**RL-5**	**RL-6**	**RL-7**	**SKR-1**	**SR-1**	**SR-2**	**SR-3**	**Average**
Arsenic	5.7	4.3	5.5	1	1	0.8	2.8	2.3	2.4	2.1	2.1	2.81
Cadmium	1.9	2.3	0.7	0.3	0.3	0.2	0.5	0.3	0.6	0.6	0.6	0.34
Chromium	18	31	32	8	9	11	15	18	26	32	38	10.83
Cobalt	12	14	15	3.7	3.4	3.5	4.9	6.3	8.5	8	9	3.73
Lead	71	140	20	6	8	15	47	6	30	39	32	9.92
Nickel	15	24	21	4.8	4.8	5.1	7.9	9.3	15	17	19	6.07

Moira River from Deloro to Moira Lake (Study Area A)

Arsenic, cadmium, cobalt, chromium, lead, and nickel concentrations in sediments were found to be significantly higher in Study Area A ($p < 0.05$) than at reference sites. Therefore, these substances in sediment were evaluated further in the PQRA. Data from Study Area A are provided in Table 3.3-11.

Table 3.3-11
Study Area A Sediment Samples (µg/g dry), Sampled April 1, 1999

	MR-4	MR-5	MR-6	MR-7	MR-8	YC-1	MR-9	MR-10	MR-11
Parameter	0.4 m	1.5 m	<1 m	<1 m	<1 m	3.0 m	<1 m	3.5 m	>1
Arsenic	140	170	280	500	1300	3000	260	260	660
Cadmium	0.3	0.6	0.4	0.5	0.5	1.9	1.2	1.5	2.6
Chromium	78	59	55	65	61	110	40	35	50
Cobalt	25	140	240	450	440	1600	540	740	1100
Lead	11	25	25	22	20	56	24	28	66
Nickel	33	77	250	550	520	1000	440	470	680

Moira Lake (Study Area B)

Arsenic, cobalt and nickel were found to have significantly higher concentrations in Study Area B sediments ($p < 0.05$) than at reference sites. Therefore, these substances were evaluated further in the PQRA. Data from Study Area B are provided in Table 3.3-12.

Stoco Lake (Study Area C)

The concentrations of arsenic, cobalt and nickel were found to be significantly higher concentrations in Study Area C sediments ($p < 0.05$) than at reference sites. These substances in sediments were evaluated further in the PQRA. Data from Study Area C are provided in Table 3.3-13.

Table 3.3-12
Study Area B Sediment Samples (µg/g dry), Sampled April 1, 1999

	ML-1	ML-2	ML-3	ML-4	ML-5	ML-6	ML-7	ML-8	ML-9	ML-10	ML-11	ML-12	ML-13	ML-14
Parameter	> 4 m	> 4 m	> 4 m	> 4 m	> 4 m	1 m	> 1 m	1 m	> 1 m	1 m	> 1 m	1 m	> 1 m	> 1 m
Arsenic	310	290	600	150	150	110	210	15	57	8.8	17	100	170	31
Cadmium	3	2.6	2.3	0.8	1	1.2	0.5	0.2	0.5	0.2	0.2	0.5	0.9	0.4
Chromium	29	38	27	19	10	13	5	10	27	13	11	11	7	7
Cobalt	770	760	760	420	420	250	190	39	83	26	47	140	350	68
Lead	81	92	140	40	27	27	30	5	16	6	7	18	18	7
Nickel	590	640	460	320	260	240	100	33	72	22	36	83	270	36

Table 3.3-13
Study Area C Sediment Samples (µg/g dry), Sampled April 1, 1999

	MR-12	SL-1	SL-2	SL-3	SL-4	SL-5	SL-6	SL-7	SL-8	SL-9	SL-10	SL-11	SL-12	SL-13	SL-14	SL-15
Parameter	3.5 m	4 m	5 m	4 m	9 m	7 m	1 m	> 1 m	1 m	> 1 m	1 m	> 1 m	1 m	> 1 m	1 m	> 1 m
Arsenic	17	42	99	96	130	54	6.3	12	16	36	6.2	7.5	4.6	2.9	2.6	3.9
Cadmium	0.6	0.8	2.3	0.4	2.2	2.7	0.2	0.4	0.4	0.7	0.2	0.2	0.2	0.2	0.2	0.3
Chromium	18	29	50	18	48	43	18	25	19	27	9	7	12	6	9	8
Cobalt	45	68	200	77	140	76	4.6	12	12	20	5.2	6.2	3	3.7	3.9	6.4
Lead	11	29	84	14	78	71	15	30	9	16	3	3	3	2	2	4
Nickel	24	41	130	37	92	63	11	16	18	31	6.2	5.8	4.6	4.9	4.6	5.8

Moira River Downstream of Stoco Lake (Study Area D)

Arsenic and cadmium had significantly higher concentrations in sediments from Study Area D ($p < 0.05$) than at reference sites. However, cadmium concentrations in sediments from Study Areas B and C were not elevated relative to the control sites. If the Deloro Mine Site is the source of cadmium to the river system, it is expected that cadmium would also be detected in Study Areas B and C at elevated concentrations relative to the reference sites. Since this is not the case, it was concluded that the elevated concentration of cadmium in Study Area D is not due to the Deloro Mine Site, but rather is likely due to a local source of cadmium to the Moira River. Therefore, cadmium in sediments in Study Area D was not evaluated further in the PQRA. Data from Study Area D are provided in Table 3.3-14.

Table 3.3-14
Study Area D Sediment Samples, Sampled April 1, 1999

Parameter	MR-13	MR-14	MR-15	MR-16
	1.5 m	1.0 m	1.3 m	0.3 m
Arsenic	50	21	11	29
Cadmium	2.5	0.8	0.3	0.9
Chromium	35	21	10	22
Cobalt	150	55	33	38
Lead	51	26	9	69
Nickel	73	34	14	26

Summary of Substances of Potential Concern in Sediments:

The results of the chemical screening process indicated that arsenic, cadmium, cobalt, chromium, lead, and nickel were present in sediments in the study areas at concentrations greater than the reference locations, as summarized in Table 3.3-15.

Table 3.3-15
Substances in Sediment Which Require Further Assessment in the PQRA

Priority Substance	Area A	Area B	Area C	Area D
Arsenic	✓	✓	✓	✓
Cadmium	✓			
Chromium	✓			
Cobalt	✓	✓	✓	
Lead	✓			
Nickel	✓	✓	✓	

Since the concentrations of these metals in sediments downstream of the Deloro Mine Site were elevated relative to the reference locations, these substances were evaluated further in the PQRA (Section 3.4).

3.3.1.3 Fish

Substances of potential concern identified in sediment in each of the four study areas were also considered with respect to exposures from consumption of fish. Concentrations of metals in sport fish fillets are provided in Table 3.3-16. These data were obtained from the MOE Sport Fish Contaminant Monitoring Program.

The MOE data indicated that metals including lead, nickel, cadmium, chromium and arsenic were found in fish tissue, but not at levels which would suggest a need for consumption restrictions (MOE, 1999). As discussed in the environmental health risk assessment conducted for the Village of Deloro, background concentrations of arsenic in fish from Ontario and other parts of Canada range from 0.1 to 0.4 µg/g (wet weight) (CanTox, 1999). This is consistent with the levels of arsenic present in fish in the all of the study areas except for northern pike, rock bass and smallmouth bass in Study Area A. Nevertheless, exposure to these metals due to the consumption of fish from the Moira River system were evaluated further in the PQRA.

3.3.2 Exposure Characterization

The river system from Moira Lake downstream is used recreationally for swimming and fishing, and the surrounding areas are either wooded or used for agriculture. There are numerous residences and cottages located adjacent to the lakes within the study area. Upstream from Moira Lake there are few cottages and limited opportunities for in-water recreation because of the rocky nature of the river substrate. As discussed previously (see Section 3.1.1), the majority of residents in the study area do not drink water from the river system, but there are a few individuals that indicated in the water use survey that they use water from the system as potable water. These individuals received a reminder letter to avoid drinking untreated surface water (Appendix IX).

Table 3.3-16
Average Metal Concentration (and Standard Deviation) in Sport Fish Fillets per Location (µg/g wet weight)

Location	Species	Metals				Samples (n)
		Arsenic	Cadmium	Lead	Nickel	
STUDY AREA A: MOIRA RIVER	Largemouth Bass	0.267±0.02	0.029±0.02	0.020±0.00	0.020±0.00	3
	Northern Pike	0.768±0.50	0.050±0.00	0.083±0.13	0.020±0.00	4
	Pumpkinseed	0.413±0.11	0.054±0.01	0.020±0.00	0.020±0.00	4
	Rock Bass	0.675±0.22	0.047±0.00	0.020±0.00	0.020±0.00	4
	Smallmouth Bass	1.113±0.33	0.026±0.02	0.020±0.00	0.020±0.00	8
	Yellow Perch	0.140	0.042	0.020	0.020	1
Average		0.719±0.43	0.039±0.02	0.030±0.05	0.020±0.00	24
STUDY AREA B: MOIRA LAKE	Largemouth Bass	0.27	0.04	0.6	0.4	1
	Northern Pike	0.13	0.04	0.6	0.4	1
	Smallmouth Bass	0.218±0.10	0.139±0.49	0.47±0.15	0.427±0.36	20
	Walleye	0.052±0.03	0.055±0.10	0.511±0.27	0.664±0.78	44
Average		0.107±0.10	0.080±0.28	0.501±0.24	0.584±0.67	66
STUDY AREA C: STOCO LAKE	Brown Bullhead	0.168±0.07	0.005±0.00	0.046±0.06	0.020±0.00	10
	Largemouth Bass	0.084±0.02	0.025±0.02	0.020±0.00	0.047±0.04	10
	Northern Pike	0.065±0.04	0.005±0.00	0.124±0.13	0.020±0.00	8
	Pumpkinseed	0.133±0.05	0.005±0.00	0.118±0.20	0.020±0.00	4
	Rock Bass	0.131±0.05	0.010±0.01	0.132±0.13	0.062±0.08	9
	Smallmouth Bass	0.166±0.15	0.012±0.01	0.241±0.12	0.091±0.08	10
	Walleye	0.045±0.06	0.017±0.01	0.175±0.14	0.103±0.07	14
	Yellow Perch	0.056±0.01	0.005±0.00	0.092±0.12	0.020±0.00	5
Average		0.091±0.09	0.013±0.01	0.136±0.14	0.064±0.07	70
STUDY AREA D: MOIRA R. HWY 37	Brown Bullhead	0.136±0.03	0.009±0.01	0.060±0.07	0.052±0.04	10
	Largemouth Bass	0.142±0.05	0.013±0.01	0.020±0.00	0.045±0.04	6
	Northern Pike	0.232±0.10	0.030±0.02	0.020±0.00	0.020±0.00	6
	Pumpkinseed	0.225±0.04	0.016±0.01	0.058±0.04	0.100±0.08	4
	Rock Bass	0.138±0.04	0.022±0.01	0.038±0.04	0.039±0.06	9
	Smallmouth Bass	0.670±0.31	0.017±0.00	0.020±0.00	0.020±0.00	3
	Walleye	0.100±0.02	0.025±0.02	0.020±0.00	0.020±0.00	4
Average		0.196±0.16	0.018±0.01	0.037±0.04	0.043±0.05	42

The exposure pathway analysis describes how humans may come into contact with the substances of concern. Considering that human receptors may reside on the river system all year and may come into contact with the chemicals detected in sediments, water and fish, various potential pathways of exposure were examined.

Mean sediment concentrations for each substance present in the study areas at elevated concentrations collected in samples at depths of 1 m or less were used for the exposure modelling (Table 3.4-1). Use of these shallow water sediment samples is appropriate since it is considered unlikely that a child aged 5 - 11 (i.e., receptor) will come into contact with sediments at depths much greater than 1 metre. Exposure was estimated using sediment concentrations, along with receptor body weight, ingestion rate, dermal contact rate, time activity patterns (i.e., time spent swimming) and chemical bioavailability.

Table 3.3-17 is a summary of the exposure pathways that were considered in this assessment.

Table 3.3-17
Summary of Exposure Pathways Considered

Environmental Matrix	Description of Exposure Pathway	Pathway Number
Water	Consumption for drinking water or cooking	1
Water	Accidental ingestion during recreational activities (e.g., swimming)	2
Water	Dermal contact during recreational activities	3
Water	Dermal contact while bathing/showering	4
Shallow Water Sediment	Accidental ingestion during recreational activities	5
Shallow Water Sediment	Dermal contact during recreational activities	6
Fish	Ingestion of fish from the river system	7

Equations and a detailed description of the input variables that were used for the exposure modelling for each pathway are given in Table 3.3-18 (non-cancer endpoints) and Table 3.3-19 (cancer endpoints).

Table 3.3-18
Exposure Pathway Equations and Input Variables for Non-Carcinogenic Effects

Exposure Pathway	Description of Exposure	Exposure Pathway Calculations			Value
1	**Consumption of drinking water**	**DWE**	**=**	**(DWC x CW x OB) / BW**	
	where:	DWE	=	drinking water exposure (µg/kg/day)	Calculated
		DWC	=	daily drinking water consumption (L/day)	1.56 L
		CW	=	metal concentration in water (µg/L)	See Table 3.4-1
		OB	=	oral bioavailability (unitless)	See Table 3.4-3
		BW	=	body weight (kg)	32.9 kg
2	**Accidental ingestion of water while swimming**	**AIW**	**=**	**[WI x CW x OB] / BW**	
	where:	AIW	=	accidental ingestion of water (µg/kg/day)	Calculated
		WI	=	water ingestion (L/event)	0.05L
		CW	=	metal concentration in water (µg/L)	See Table 3.4-1
		OB	=	oral bioavailability (unitless)	See Table 3.4-3
		BW	=	body weight (kg)	32.9 kg
3	**Dermal contact with water (recreational)**	**DWE**	**=**	**[C x P x SA x ET x 10^{-3}]/BW**	
	where:	DWE	=	dermal water exposure (µg/kg/day)	Calculated
		C	=	metal concentration in water (µg/L)	See Table 3.4-1
		P	=	permeability constant	0.0001 cm^2/hr
		SA	=	surface area of exposed skin (m^2)	7840 cm^2
		ET	=	exposure time	1 hr
		BW	=	body weight (kg)	32.9 kg
4	**Dermal contact with water (bathing/ showering)**	**DWE**	**=**	**[C x P x SA x ET x 10^{-3}]/BW**	
	where:	DWE	=	dermal water exposure (µg/kg/day)	Calculated
		C	=	metal concentration in water (µg/L)	See Table 3.4-1
		P	=	permeability constant	0.0001 cm^2/hr
		SA	=	surface area of exposed skin (m^2)	13,500 cm^2
		ET	=	exposure time	0.5 hr
		BW	=	body weight (kg)	32.9 kg

5	**Accidental ingestion of sediment**	**AIS**	**=**	**[SI x CS x OB] / BW**	
	where:	AIS	=	accidental ingestion of sediment (μg/kg/day)	Calculated
		SI	=	sediment ingestion (g/day)	0.2 g/day
		CS	=	metal concentration in sediment (μg/g)	See Table 3.4-1
		OB	=	oral bioavailability (unitless)	See Table 3.4-3
		BW	=	body weight (kg)	32.9 kg
6	**Dermal contact with sediment**	**DSE**	**=**	**[C x A x BF x 10-3] / BW**	
	where:	DSE	=	dermal sediment exposure (μg/kg/day)	Calculated
		C	=	concentration of substance	See Table 3.4-1
		A	=	soil adherence	7.8 g/m^2/day
		BF	=	bioavailability factor	See Table 3.4-3
		BW	=	body weight (kg)	32.9 kg
7	**Ingestion of fish**	**EFF**	**=**	**DFC x CF x OB / BW**	
	where:	EFF	=	exposure from fish (μg/kg/day)	Calculated
		CF	=	concentration of substance in fish	See Table 3.4-1
		OB	=	oral bioavailability (unitless)	See Table 3.4-3
		CF	=	daily fish consumption (g/day)	20.2 g/day
		BW	=	body weight (kg)	32.9 kg

Adopted from CanTox, 1999 and Health Canada, 1995.

Table 3.3-19
Exposure Pathway Equations and Input Variables for Cancer Assessment

Exposure Pathway	Description of Exposure	Exposure Pathway Calculations	Value
1	**Consumption of drinking water**	**DWE = (DWC x CW x OB) / BW**	
	where:	DWE = Drinking water exposure (µg/kg/day)	Calculated
		DWC = daily drinking water consumption (L/day)	See Table 3.3-20
		CW = metal concentration in water (µg/L)	See Table 3.4-1
		OB = oral bioavailability (unitless)	See Table 3.4-3
		BW = body weight (kg)	See Table 3.3-20
2	**Accidental ingestion of water while swimming**	**AIW = [WI x CW x OB x F] / BW x AT**	
	where:	AIW = accidental ingestion of water (µg/kg/day)	Calculated
		WI = water ingestion (L/event)	See Table 3.3-20
		CW = metal concentration in water (µg/L)	See Table 3.4-1
		OB = oral bioavailability (unitless)	See Table 3.4-3
		F = frequency of events	60 days
		AT = averaging time	365 days
		BW = body weight (kg)	See Table 3.3-20
3	**Dermal contact with water (recreational)**	**DWE = [C x P x SA x ET x F x 10^{-3}] / BW x AT**	
	where:	DWE = dermal water exposure (µg/kg/day)	Calculated
		C = metal concentration in water (µg/L)	See Table 3.4-1
		P = permeability constant	0.0001 cm^2/hr
		SA = surface area of exposed skin (m^2)	See Table 3.3-20
		ET = exposure time	1 hr
		F = frequency of events	60 days
		AT = averaging time	365 days
		BW = body weight (kg)	See Table 3.3-20
4	**Dermal contact with water (bathing/ showering)**	**DWE = [C x P x SA x ET x F x 10^{-3}] / BW x AT**	
	where:	DWE = dermal water exposure (µg/kg/day)	Calculated
		C = metal concentration in water (µg/L)	See Table 3.4-1
		P = permeability constant	0.0001 cm^2/hr
		SA = surface area of exposed skin (m^2)	See Table 3.3-20
		ET = exposure time	0.5 hr
		F = frequency of events	365 days
		AT = averaging time	365 days
		BW = body weight (kg)	See Table 3.3-20
5	**Accidental ingestion of sediment**	**AIS = [SI x CS x OB x F] / BW x AT**	
	where:	AIS = accidental ingestion of sediment (µg/kg/day)	Calculated
		SI = sediment ingestion (g/day)	See Table 3.3-20
		CS = metal concentration in sediment (µg/g)	See Table 3.4-1
		OB = oral bioavailability (unitless)	See Table 3.4-3
		F = frequency of events	60 days
		AT = averaging time	365 days
		BW = body weight (kg)	See Table 3.3-20
6	**Dermal contact with sediment**	**DSE = [C x A x BF x F x 10^{-3}] / BW x AT**	
	where:	DSE = dermal sediment exposure (µg/kg/day)	Calculated
		C = concentration of substance	See Table 3.4-1
		A = soil adherence	See Table 3.3-20
		BF = bioavailability factor	See Table 3.4-3
		F = frequency of events	60 days
		AT = averaging time	365 days
		BW = body weight (kg)	See Table 3.3-20
7	**Ingestion of fish**	**EFF = DFC x CF x OB / BW**	

	where:	EFF	=	exposure from fish (μg/kg/day)	Calculated
		CF	=	concentration of substance in fish	See Table 3.4-1
		OB	=	oral bioavailability (unitless)	See Table 3.4-3
		CF	=	daily fish consumption (g/day)	20.2 g/day
		BW	=	body weight (kg)	See Table 3.3-20

Adopted from CanTox, 1999 and Health Canada, 1995.

Other potential pathways of exposure were not considered to be significant pathways of exposure to the substances of concern. For example, inhalation of particulates derived from sediments is possible, but was considered negligible relative to the six pathways identified above.

3.3.3 Receptor Selection

For this assessment, a child aged 5 to 11 years old was identified as the most appropriate human receptor to evaluate potential non-cancer effects. This age group was selected as the critical receptor because the physical characteristics and activity patterns for children of this age make them the most likely to have the greatest exposure on a body weight basis. For example, they generally spend more time outdoors swimming and playing along the river and lakes than either adults or younger children, and are expected to have higher levels of exposure on a body weight basis due to their physical characteristics. Use of this receptor therefore represents a conservative (i.e., protective) approach to the PQRA.

Parameters describing the physiological and behavioural characteristics of the 5-11 year-old child are given in Table 3.3-20. Maximum plausible receptor characteristics such as ingestion rate and body surface area were employed and are expected to overestimate actual exposure.

Table 3.3-20
Receptor Characteristics by Lifestage

	Preschool Child	Child (5-11 years)	Adolescent	Adult
Body Weight	16.5 kg	32.9 kg	59.7 kg	70.7 kg
Sediment Ingestion	0.2 g/day	0.2 g/day	0.1 g/day	0.1 g/day
Water Ingestion	1.35 L/day	1.56 L/day	2.13 L/day	3.014 L/day
Sediment Adherence Factor	10 g/m^2/day	10 g/m^2/day	10 g/m^2/day	10 g/m^2/day
Exposed Skin in Summer	0.463 m^2	0.784 m^2	1.16 m^2	1.22 m^2
Total Surface Area	0.799 m^2	1.35 m^2	1.94 m^2	2.13 m^2
Frequency of Swimming Events	60 day/year	60 day/year	60 day/year	60 day/year

Arsenic is the only substance addressed in this study that may cause cancer by ingestion or dermal contact. To estimate the increased cancer risk associated with arsenic, it is necessary to determine the average daily dose of arsenic to which a person is exposed over an entire lifetime. This dose, termed the Lifetime Average Daily Dose (LADD), is multiplied by the cancer potency factor for arsenic to estimate the associated increased cancer risk. Because it is necessary to model exposures over a lifetime, arsenic exposures over four life stages (i.e., preschool child, child, adolescent and adult) were calculated. The physiological and behavioural characteristics of each life stage used for the exposure modelling are given in Table 3.3-20.

3.3.4 Summary of Conceptual Site Model

Humans may be exposed to substances of potential concern present in the water and shallow sediments from the Moira River system via drinking water and using the river system for recreational activities. Exposure is also possible via the consumption of fish caught in the river system. The CSM, which has been developed for this assessment, is provided in Figure 3.3-1.

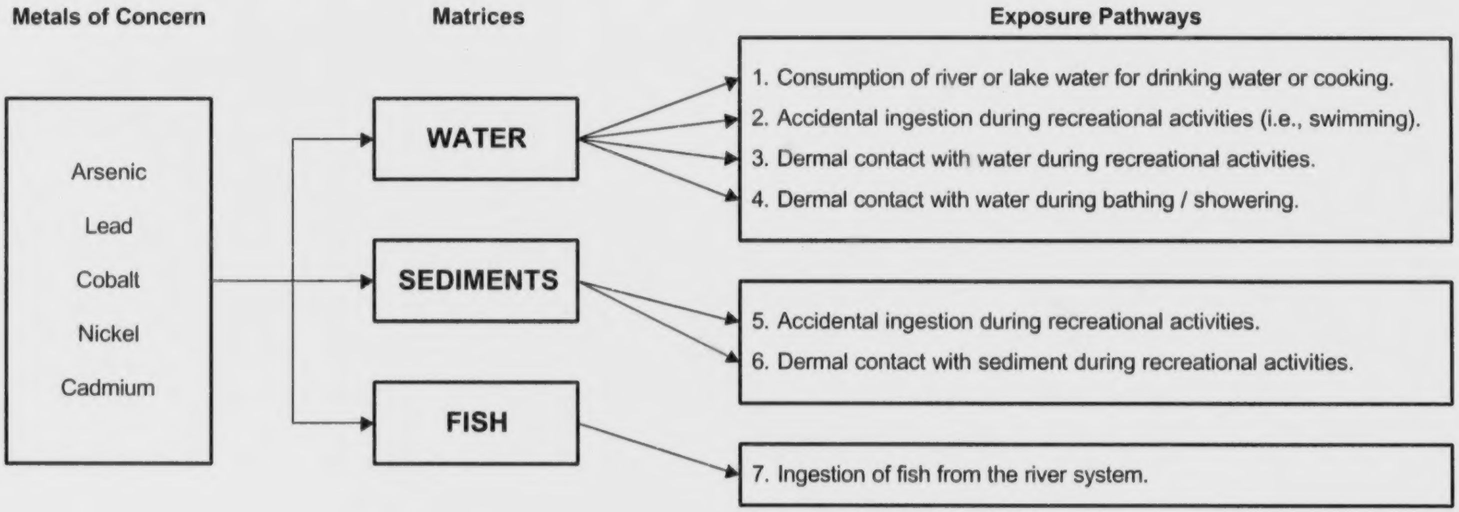
3.4 Preliminary Quantitative Risk Assessment

The PQRA is a semi-quantitative process of evaluating the potential risk to human health resulting from exposure to the priority substances identified in the Moira River system. The methodology and assumptions adopted for this assessment were consistent with those used in the environmental health risk assessment conducted for the Village of Deloro (CanTox 1999).

3.4.1 Exposure Assessment

The exposure assessment characterized the potential exposures of the receptor to substances of concern. The methodology, rationale and underlying assumptions used in the exposure assessment are outlined in the following sections (see also Tables 3.3-18 and 3.3-19).

Figure 3.3-1
Conceptual Site Model


Metals of Concern
Matrices
Exposure Pathways
Arsenic
Lead
Cobalt
Nickel
Cadmium
WATER
SEDIMENTS
FISH
1. Consumption of river or lake water for drinking water or cooking.
2. Accidental ingestion during recreational activities (i.e., swimming).
3. Dermal contact with water during recreational activities.
4. Dermal contact with water during bathing / showering.
5. Accidental ingestion during recreational activities.
6. Dermal contact with sediment during recreational activities.
7. Ingestion of fish from the river system.

A deterministic modelling approach was adopted for this PQRA. Conservative (i.e., health-protective) point estimates for all parameters used to describe exposure and toxicity were incorporated into this assessment. For example, maximum plausible estimates of receptor characteristics including body weight, body surface area and water consumption were used. This approach is expected to result in exposure estimates that are greater than actual exposures.

Two concentrations of the substances of potential concern in water were used for the exposure assessment. The annual average concentration of each substance was used to produce a "reasonable maximally exposed" (RME) estimate. Additionally, the ten-year average of the annual maximum concentrations detected in water from 1990 to present was used to represent a worst-case exposure scenario. The water concentrations used for the exposure modelling are given in Table 3.4-1. Exposure estimates were calculated using water concentrations, along with receptor body weight, water consumption rate, accidental ingestion rate, dermal contact rate, time activity patterns (i.e., time spent swimming) and chemical bioavailability.

Mean sediment concentrations for each substance of concern in samples collected at depths of 1 m or less for each study area were used for the exposure modelling (Table 3.4-1). It is considered unlikely that the receptor selected will come into contact with sediments at depths greater than 1 m. The mean metal concentrations presented in Table 3.4-1 are different than the mean concentrations for "near-shore" presented in Section 2 (Table 2.2-5). The "near-shore" concentrations in Table 2.2-5 are for both one-metre and two-metre depths. Exposure was estimated using sediment concentrations, along with receptor body weight, ingestion rate, dermal contact rate, time activity patterns (i.e., time spent swimming) and chemical bioavailability.

Mean fish fillet concentrations of the substances of potential concern from the 1999 MOE sport fish sampling program were used for the exposure modelling and are given in Table 3.4-1.

Table 3.4-1
Chemical Concentrations Employed in Exposure Assessment

	Area A				Area B			
	Water – Average	Water – Average Maximum	Sediment	Fish	Water - Average	Water - Average Maximum	Sediment	Fish
Parameter	µg/L	µg/L	µg/g	µg/g	µg/L	µg/L	µg/g	µg/g
Arsenic	46.4	160.3	496.0	0.7	28.4	73.9	58.5	0.7
Cadmium	NA	NA	0.6	0.0	NA	NA	NA	0.0
Chromium	NA	NA	59.8	NA	NA	NA	NA	NA
Cobalt	8.3	31.1	339.0	NA	NA	NA	113.8	NA
Lead	NA	NA	20.4	0.0	NA	NA	NA	0.0
Nickel	NA	20.0	358.6	0.0	NA	NA	94.5	0.0

	Area C				Area D			
	Water - Average	Water - Average Maximum	Sediment	Fish	Water – Average	Water - Average Maximum	Sediment	Fish
Parameter	µg/L	µg/L	µg/g	µg/g	µg/L	µg/L	µg/g	µg/g
Arsenic	NA	NA	7.1	0.1	NA	NA	25.0	0.2
Cadmium	NA	NA	NA	0.0	NA	NA	0.9	0.0
Chromium	NA	NA	NA	NA	NA	NA	NA	NA
Cobalt	NA	NA	5.7	NA	NA	NA	NA	NA
Lead	NA	NA	NA	0.1	NA	NA	NA	0.037
Nickel	NA	NA	8.9	0.033	NA	NA	NA	0.043

3.4.2 Toxicity Assessment

The toxicological criteria and bioavailability factors used in this assessment were adopted from the environmental health risk assessment conducted for the Village of Deloro (CanTox 1999). Table 3.4-2 is a summary of the toxicological criteria and the bioavailability factors for the substances of potential concern are given in Tables 3.4-3 and 3.4-4. Regulatory agencies such as Health Canada and the US EPA have developed these values. Appendix VI provides a summary of the toxicological properties for arsenic, cadmium, chromium, cobalt, lead and nickel. A more complete description of the toxicological properties of these substances is given elsewhere (CanTox 1999).

Table 3.4-2
Toxicological Criteria of Substance of Potential Concern

Chemical	Route	Toxicological Criterion		Endpoint	Study	Regulatory Agency
		Type	Value			
Arsenic (non-carcinogenic)	Oral	RfD	0.3 µg/kg/day	Hyperpigmentation, keratosis, possible vascular complications (human).	Tseng et al., 1968; Tseng, 1977	U.S. EPA, 1998
Arsenic (carcinogenic)	Oral	q_1	0.0015 µg/kg/day	Skin cancer, basal and squarmous cell carcinoma (human).	Tseng et al., 1968; Tseng, 1977	U.S. EPA, 1998
Cadmium (non-carcinogenic)	Oral (water)					

Table 3.4-3
Bioavailability Factors Identified in Literature

Chemical	Bioavailability (%)			
	Oral	Reference	Dermal	Reference
Arsenic	95% 90% 14%	in drinking water: Pomroy et al., 1980 in food: OMOE, 1994b in soil: Freeman et al., 1995	0.8 - 1.9%	Wester et al., 1993
Cobalt	18-97%	Harp and Scoular, 1952; Sorbie et al., 1971; Valberg et al., 1969	0.06%	Assumed[a]
Lead (Child)	42-53	Karhausen, 1973; Alexander, 1974; Ziegler et al., 1978; Mushak, 1991	0.06%	Moore et al., 1980
Nickel	27% 1%	Water Food (Nieboer et al., 1992; ATSDR, 1997)	0.06%	Assumed[a]
Cadmium	0.7-15.6%	McLellan et al, 1978	0.5 - 1%	US EPA 1978; CEC 1978; Carson et al, 1986; Westar et al, 1992
Chromium	0.5-2.0%	ATSDR, 1993		No value identified in ATSDR or HSDB.

a - assumed to be the same dermal bioavailability as lead due to lack of data.
Information adopted from CanTox, 1999.

Table 3.4-4
Bioavailability Factors Used for Exposure Modelling

Metal	Bioavailability (percent)			
	Water	Sediment	Fish	Dermal
Arsenic	95.00	14.00	90.00	1.35
Cobalt	97.00	57.50	57.50	0.1
Nickel	27.00	1.00	1.00	0.1
Cadmium	15.60	8.15	8.15	1
Chromium	2.00	1.25	1.25	0.1

3.4.3 Risk Characterization

Risk characterization was the final step in the risk assessment and involves comparing the estimated exposures to benchmark values that represent safe or acceptable exposures. Comparison of the estimated exposures to those typically encountered in the general population was also an important aspect of risk characterization, since it provided a frame of reference to evaluate local conditions. This step also identified the relative contribution to total exposure of each individual exposure scenario and allowed specific substances and exposure pathways that required further evaluation or management to be identified. Finally, uncertainties in the assessment, and their impact on its conclusions, were identified.

This section describes the results of the PQRA. Exposure modelling and calculation of Exposure Ratios (ERs) and Cancer Risk Levels (CRLs) was performed using Microsoft Excel™. The calculation of ERs and CRLs was completed individually for Study Areas A through D.

3.4.3.1 Non-Cancer Endpoints

Chemicals that do not cause cancer have a threshold-type dose-response; i.e., effects do not occur unless the dose is above a certain threshold. Risk characterization for these chemicals involves comparing the total estimated daily dose (i.e., exposure) to the Reference Dose (RfD). The RfD defines the amount of chemical that humans, including sensitive sub-populations, may be exposed to on a daily basis for an entire lifetime without an adverse effect. An Exposure Ratio (ER) is calculated by dividing the estimated exposure by the RfD, as summarized below.

$$\textbf{\textit{Exposure Ratio}} = \frac{\textbf{\textit{Estimated Exposure}}}{\textbf{\textit{RfD}}}$$

ER values less than one are considered safe, and no adverse effects are expected. Conversely, ER values greater than one may represent a health risk, and therefore, need to be considered further. Because of the conservative nature of this assessment, ER values greater one may not represent a significant risk (see Section 3.4.3.7). In these instances, additional interpretation of the results is needed.

To put into perspective the relative importance of the potential health risks to residents of the Moira River system due to the presence of arsenic, calculated ER values for arsenic in each study area were also compared to ER values for arsenic calculated for a "Typical Ontario Resident" (TOR). The following ER values for arsenic were calculated for the TOR and have been adopted for this assessment.

- ***ER Values for TOR (Child Aged 5 - 11 Years):*** 6.31 (plausible maximum), 0.53 (mean), 0.49 (5th percentile), 2 (50th percentile), and 4.77 (95th percentile).

These ER values for the TOR have been described in the environmental health risk assessment for the Village of Deloro (CanTox, 1999), and are representative of the health risks typically encountered by the average Ontario resident as calculated using standard risk assessment methodology. It is clear from ER values for the TOR that even individuals not exposed to localized sources of arsenic may be expected to have ER values greater than one. This illustrates the conservative nature of ER values; i.e., there are several layers of safety built into their estimation. Because of these layers of safety, ER values have to be considerably greater than one to represent significant potential risk.

Additionally, to gain a better understanding of the potential risks associated with the various pathways by which residents may be exposed to substances in the Moira River system, ERs were calculated for two exposure pathway groupings identified as Scenario A (exposure pathways 1 - 7) and Scenario B (exposure pathways 2 - 7). Scenario A assumes that water from the Moira River system is used as a source of potable water and for recreation and fishing, whereas Scenario B assumes that the river system is not used as a source of potable water, but is used for recreation and fishing.

3.4.3.2 Cancer

Carcinogens are usually assumed to have a non-threshold type dose response. So as to not underestimate potential health risks, it is assumed that there is some risk associated with any exposure. This is a conservative assumption that is used to ensure protection of public health. Risk characterization of carcinogens involves calculating a Cancer Risk Level (CRL). The CRL is calculated by multiplying the estimated Lifetime Average Daily Dose (LADD) of a chemical by the cancer potency factor (i.e., slope factor, or q*) of that chemical, as outlined below.

$$CRL = LADD \times q^*$$

The CRL defines the predicted excess risk that an individual has of developing cancer in their lifetime as a result of a particular exposure to a substance. Additionally, it should be noted that the determination of CRLs considers both long-term (chronic) and short-term (acute) exposures.

For carcinogens, the toxicological endpoint of interest is the incremental lifetime risk of developing cancer. Since a lifetime is commonly defined as 70 years, the LADD is calculated by amortizing the total lifetime dose over 70 years, even if the exposure is less than a lifetime. The CRL is calculated by multiplying the LADD by the chemical-specific cancer potency factor (q*). The q* is used to define the ability of a chemical to cause cancer in humans. Comparison of the calculated CRL values to cancer risk levels that are *de minimus* (i.e., negligible) is done to determine if the calculated cancer risks are acceptable. Regulatory agencies generally consider CRLs ranging from 1×10^{-6} (1 in 1 million) to 1×10^{-4} (1 in ten thousand) as *de minimus* risk levels.

The calculated CRLs were also compared to the CRLs derived for the TOR (composite receptor), as discussed in the environmental health risk assessment for the Village of Deloro (CanTox, 1999). The CRLs for arsenic for the TOR are summarized below. Arsenic is the only metal evaluated in this study that is carcinogenic.

- ***CRL Values for TOR (Composite Receptor):*** 1.4×10^{-3} (plausible maximum), 2.6×10^{-4} (mean), 3.2×10^{-4} (5th percentile), 5.4×10^{-4} (50th percentile), and 8.2×10^{-4} (95th percentile).

The calculated CRLs for the TOR are greater than *de minimus* levels. This indicates that the average Ontario resident is typically exposed to elevated levels of arsenic (predominantly via the uptake of arsenic from food).

3.4.3.3 Moira River from Deloro to Moira Lake (Study Area A)

Non-Carcinogens

The estimated exposure for the child receptor (age 5 to 11 years) to the substances of concern present in Study Area A is given in Table 3.4-5, and the calculated ERs based on these exposure estimates are given in Table 3.4-6. The key findings are as follows.

Cadmium, Chromium, Cobalt, Lead and Nickel: These metals all had ER values less than 1 under all model scenarios. Therefore, these substances do not represent a health risk to users of the Moira River system, and do not require further evaluation.

Arsenic – Scenario A: Assuming the water from the river system is used for drinking water, ER values ranging from approximately 13 (average concentrations) to more than 31 (average of the maximum concentrations) were calculated. Comparison of these ER values to the TOR reveals that residents that consume river water in Study Area A are potentially exposed to levels of arsenic that are at least 2 to 5 times greater than the plausible maximum ER value calculated for the TOR. This finding indicates that residents that consume water from the Moira River in Study Area A are likely to be exposed to greater levels of arsenic than the TOR.

Examination of the seven exposure pathways reveals that more than 83 percent of the total exposure (approximately 18 µg/kg/day) is estimated to be derived from drinking water from the river assuming maximum average arsenic concentrations in water. Recreational uses of the river account for approximately 15 percent of the total estimated exposure. Clearly, consumption of water from the river is the single most important exposure pathway under this scenario.

Table 3.4-5
Estimated Exposures for Child Receptor: Study Area A Non-Cancer Endpoints

Exposure Pathway	Exposure Pathway Description	Estimated Exposure (ug/kg/day) arsenic max	arsenic avg	cadmium max	cadmium avg	chromium max	chromium avg	cobalt max	cobalt avg	lead max	lead avg	nickel max	nickel avg
1	consumption of water	7.221	2.090	na	na	na	na	1.430	0.382	na	na	0.256	na
2	accidental ingestion of water	0.463	0.134	na	na	na	na	0.092	0.024	na	na	0.016	na
3	dermal contact - swimming	0.004	0.001	na	na	na	na	0.001	0.000	na	na	0.000	na
4	dermal contact - bathing/shower	0.007	0.002	na	na	na	na	0.001	0.000	na	na	0.001	na
5	accidental ingestion of sediment	0.844	0.844	0.001	0.001	0.009	0.009	2.370	2.370	0.143	0.143	0.044	0.044
6	dermal contact with sediment	0.397	0.397	0.000	0.000	0.004	0.004	0.020	0.020	0.001	0.001	0.021	0.021
7	ingestion of fish	0.398	0.398	0.002	0.002	na	na	na	na	0.017	0.017	0.000	0.000
A	**total exposure - pathways 1 - 7**	**9.333**	**3.866**	**0.003**	**0.003**	**0.013**	**0.013**	**3.914**	**2.797**	**0.160**	**0.160**	**0.339**	**0.065**
B	**total exposure - pathways 2 - 7**	**2.112**	**1.776**	**0.003**	**0.003**	**0.013**	**0.013**	**2.484**	**2.415**	**0.160**	**0.160**	**0.08**	**0.065**

max	estimated based on the ten year average of the annual maximum concentration detected
avg	estimated based on average concentration detected
na	not applicable - screened out during chemical screening

Table 3.4-6
Calculated Exposure Ratios for Child Receptor: Study Area A Non-Cancer Endpoints

Exposure Ratios

Exposure Pathway	arsenic		cadmium		chromium		cobalt		lead		nickel	
	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg
Reference Dose (RfD)	0.30	0.30	1.00	1.00	3.00	3.00	60.00	60.00	1.85	1.85	1.30	1.30
Exposure Pathways 1 - 7	31.11	12.89	0.00	0.00	0.00	0.00	0.07	0.05	0.08	0.09	0.26	0.05
Exposure Pathways 2 - 7	7.04	5.92	0.00	0.00	0.00	0.00	0.04	0.04	0.09	0.09	0.06	0.05

max	estimated based on the ten year average of the annual maximum concentration detected
avg	estimated based on average concentration detected
▨	exposure ratio greater than 1

The exposure values calculated using average arsenic concentrations in water indicate that nearly 47 percent of the total exposure (2.1 μg/kg/day) is due to drinking water. Approximately 41 percent or 1.8 μg/kg/day of the total arsenic exposure is due to exposure to sediment (dermal contact and accidental ingestion during swimming). This indicates that exposure to sediments via recreational activities also represent an important source of exposure to arsenic in Study Area A.

Arsenic – Scenario B: Assuming that water from the river system is not used for drinking water purposes, ER values of approximately 6 and 7 were calculated based on the average and average of the maximum concentrations detected, respectively. These ER values are approximately 25 percent greater than the 95th percentile ER value and are marginally elevated relative to the maximum plausible ER value for the TOR, respectively. Relative to the 50th percentile ER value for the TOR, the calculated ER values are approximately 3 times greater. These data indicate that area residents may be expected to have marginally higher arsenic exposure levels than the TOR.

Examination of the relative importance of the 7 exposure pathways indicates that approximately 75 percent (1.8 μg/kg/day) of the total estimated arsenic exposure under this exposure scenario is due to accidental ingestion of sediment and dermal contact with sediment during swimming. In the absence of these exposure pathways, the corresponding ER value would be approximately 1.5 - 2, which is approximately equal to the 50th percentile ER value calculated for the TOR. Thus, residents using the river in Study Area A for recreational purposes may be exposed to levels of arsenic greater than the TOR.

It should be noted that approximately 75 percent of the total arsenic exposure for the TOR is derived from food. Since area residents would also be expected to have similar levels of exposure to arsenic via food, any arsenic exposures received by residents in Study Area A would be incremental (in addition) to exposures received by the TOR.

Carcinogens

The estimated daily exposures to arsenic for each life stage are given in Table 3.4-7. The LADD for each scenario and the estimated excess cancer risk associated with these LADDS are given in Table 3.4-8. The key findings are summarized below.

Arsenic – Scenario A: Assuming the water from the river system is used for drinking water, CRL values of 2.5 x 10^{-3} to 5.4 x 10^{-3} have been calculated for the average and average of the maximum water concentrations detected, respectively. These CRLs are greater than *de minimus* or negligible cancer risk levels, which are often identified by regulatory agencies as ranging from 1 x 10^{-6} to 1 x 10^{-4}. The calculated CRL values for area residents are between 2 to 4 times greater than the plausible maximum CRL (1.4 x 10^{-3}) and approximately 10 times greater than the 50th percentile CRL estimates for the TOR. This result is consistent with the result described above and indicates that residents in Study Area A are likely exposed to levels of arsenic greater than the TOR.

Arsenic – Scenario B: Assuming that water from the river system is not used for drinking water purposes, CRL values of 3.9 x 10^{-4} and 4.0 x 10^{-4} have been calculated for average and average of the maximum concentrations detected, respectively. These values are approximately 4 times greater than the lower limit of the *de minimus* risk levels, but they are similar to the CRL values estimated for the TOR. For example, the 50th percentile CRL value for the TOR is 5.4 x 10^{-4}.

These results indicate that the potential cancer risks to area residents are not significantly different than the TOR. However, it should be noted that area residents would also be exposed to arsenic from food and, as described above, approximately 75 percent of the total exposure to arsenic by the TOR are derived from food.

Based on the estimated ER values and CRL estimates, residents of Study Area A may be exposed to higher levels of arsenic than the TOR under both exposure scenarios.

Table 3.4-7
Estimated Daily Exposure to Arsenic for Each Life Stage: Study Area A Cancer Effects

		Estimated Daily Exposure (µg/kg/day)							
Exposure	Exposure Pathway	Preschool Child (7 mo. - 4 yrs)		Child (5 - 11 yrs)		Adolescent (12 - 19)		Adult	
Pathway	Description	max. avg	avg	max. avg	avg	max. avg	avg	max. avg	avg
1	consumption of water	6.4902	3.6065	3.7613	2.0901	2.8302	1.5727	3.5601	1.3280
2	accidental ingestion of water	0.0395	0.0220	0.0396	0.0220	0.0109	0.0061	0.0092	0.0051
3	dermal contact - swimming	0.0002	0.0001	0.0003	0.0002	0.0003	0.0001	0.0002	0.0001
4	dermal contact - bathing/shower	0.0023	0.0001	0.0020	0.0011	0.0016	0.0009	0.0014	0.0008
5	accidental ingestion of sediment	0.1384	0.1384	0.1388	0.1388	0.0191	0.0191	0.0161	0.0161
6	dermal contact with sediment	0.0384	0.0384	0.0652	0.0652	0.0158	0.0158	0.0050	0.0050
7	ingestion of fish	0.3979	0.3979	0.3979	0.3979	0.2193	0.2193	0.1851	0.1851
A	**daily exposure - pathways 1 - 7**	**7.1069**	**4.2033**	**4.4052**	**2.7153**	**3.0972**	**1.8340**	**3.7772**	**1.5403**
B	**daily exposure - pathways 2 - 7**	**0.6166**	**0.5968**	**0.6439**	**0.6252**	**0.2670**	**0.2613**	**0.2172**	**0.2123**

max avg	estimated based on maximum concentration detected
avg	estimated based on average concentration detected

Table 3.4-8
Estimated LADD and Lifetime Cancer Risk Due to Arsenic: Study Areas A through D

		Study Area A		Study Area B		Study Area C		Study Area D	
Exposure Pathway		max	avg	max	avg	max	avg	max	avg
	Lifetime Exposure - Pathways 1 - 7 (µg/kg/day)	91905.77	43118.56	40946.39	27702.90	9134.19	981.07	1490.17	1490.17
	LADD	3.60	1.69	1.60	1.08	0.36	0.04	0.06	0.06
A	**Lifetime Cancer Risk**	**5.40E-03**	**2.53E-03**	**2.40E-03**	**1.63E-03**	**5.36E-04**	**5.76E-05**	**8.75E-05**	**8.75E-05**
	Lifetime Exposure - Pathways 2 - 7	6800.42	6630.96	5532.13	6864.08	1018.43	981.07	1490.17	1490.17
	LADD	0.27	0.26	0.22	0.27	0.04	0.04	0.06	0.06
B	**Lifetime Cancer Risk**	**4.0E-04**	**3.9E-04**	**3.3E-04**	**4.0E-04**	**6.0E-05**	**5.8E-05**	**8.8E-05**	**8.8E-05**

max	estimated based on maximum concentration detected
avg	estimated based on average concentration detected
na	not applicable - screened out during chemical screening

3.4.3.4 Moira Lake (Study Area B)

Non-Carcinogens

The estimated exposure for the child receptor (age 5 to 11 years) to the priority metals present in Study Area B is given in Table 3.4-9, and the calculated ERs based on these exposure estimates are given in Table 3.4-10. The key findings are summarized below.

Cadmium, Chromium, Cobalt, Lead and Nickel: These metals all had exposure values less than 1 under all model scenarios, and therefore, are not expected to represent a health risk to users of the Moira River system.

Arsenic – Scenario A: Assuming that water from the river system is used for drinking water, ER values ranging from approximately 5 (average concentrations) to more than 12 (average of the maximum concentrations) were calculated. Comparison of these ER values to the TOR reveals that residents that consume river water in Study Area B are potentially exposed to levels of arsenic that are approximately equal to or twice the plausible maximum ER value calculated for the TOR. This finding indicates that residents that consume water from the Moira River in Study Area B may be exposed to greater levels of arsenic than the TOR.

Arsenic – Scenario B: Assuming that water from the river system is not used for drinking water purposes, ER values of between 1.08 and 1.53 were calculated based on the average and average of the maximum concentrations detected, respectively. These ER values are marginally greater than an ER value of one, but are less than the 50th percentile ER value for the TOR. These data indicate that residents in Study Area B are not expected to have higher arsenic exposure levels than the TOR.

Carcinogens

The estimated daily exposures to arsenic for each life stage exposed to arsenic present in Study Area B are given in Table 3.4-11. The LADD for each scenario and the estimated excess cancer risk associated with this exposure is given in Table 3.4-8. The key findings are summarized below.

Table 3.4-9
Estimated Exposures for Child Receptor: Study Area B Non-Cancer Endpoints

		Estimated Exposure (ug/kg/day)											
Exposure	Exposure Pathway	arsenic		cadmium		chromium		cobalt		lead		nickel	
Pathway	Description	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg
1	consumption of water	3.329	1.279	na	na	na	na	na	na	na	na	na	na
2	accidental ingestion of water	0.213	0.082	na	na	na	na	na	na	na	na	na	na
3	dermal contact - swimming	0.002	0.001	na	na	na	na	na	na	na	na	na	na
4	dermal contact - bathing/shower	0.003	0.001	na	na	na	na	na	na	na	na	na	na
5	accidental ingestion of sediment	0.100	0.100	na	na	na	na	0.796	0.796	na	na	0.011	0.011
6	dermal contact with sediment	0.047	0.047	na	na	na	na	0.007	0.007	na	na	0.006	0.006
7	ingestion of fish	~~0.093~~	~~0.093~~	~~0.003~~	~~0.003~~	~~na~~	~~na~~	~~na~~	~~na~~	~~0.294~~	~~0.294~~	~~0.003~~	0.003
A	**total exposure - pathways 1 - 7**	**3.787**	**1.603**	**0.003**	**0.003**	**0.000**	**0.000**	**0.802**	**0.802**	**0.294**	**0.294**	**0.020**	**0.020**
B	**total exposure - pathways 2 - 7**	**0.458**	**0.324**	**0.003**	**0.003**	**0.000**	**0.000**	**0.802**	**0.802**	**0.294**	**0.294**	0.02	**0.020**

max	estimated based on the ten year average of the annual maximum concentration detected
avg	estimated based on average concentration detected
na	not applicable - screened out during chemical screening

Table 3.4-10
Calculated Exposure Ratios for Child Receptor: Study Area B Non-Cancer Endpoints

	Exposure Ratios											
Exposure Pathway	arsenic		cadmium		chromium		cobalt		lead		nickel	
	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg
Reference Dose (RfD)	0.30	0.30	1.00	1.00	3.00	3.00	60.00	60.00	1.85	1.85	1.30	1.30
Exposure Pathways 1 - 7	12.62	5.34	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.02	0.02
Exposure Pathways 2 - 7	1.53	1.08	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.02	0.02

max	estimated based on the ten year average of the annual maximum concentration detected
avg	estimated based on average concentration detected
▨	exposure ratio greater than 1

Table 3.4-11
Estimated Daily Exposure to Arsenic for Each Life Stage: Study Area B Cancer Effects

		Estimated Daily Exposure (ug/kg/day)							
Exposure Pathway	Exposure Pathway Description	Preschool Child (7 mo. - 4 yrs) max	Preschool Child (7 mo. - 4 yrs) avg	Child (5 - 11 yrs) max	Child (5 - 11 yrs) avg	Adolescent (12 - 19) max	Adolescent (12 - 19) avg	Adult max	Adult avg
1	consumption of water	2.7982	2.0598	1.6216	1.1937	1.2202	0.8982	1.4580	0.7585
2	accidental ingestion of water	0.0170	0.0125	0.0171	0.0126	0.0047	0.4744	0.0040	0.0029
3	dermal contact - swimming	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
4	dermal contact - bathing/shower	0.0010	0.0007	0.0009	0.0006	0.0007	0.0005	0.0006	0.0005
5	accidental ingestion of sediment	0.0163	0.0163	0.0164	0.0164	0.0023	0.0023	0.0019	0.0019
6	dermal contact with sediment	0.0045	0.0045	0.0077	0.0077	0.0019	0.0019	0.0006	0.0006
7	ingestion of fish	~~0.3979~~	~~0.3979~~	~~0.3979~~	~~0.3979~~	~~0.2193~~	~~0.2193~~	~~0.1851~~	~~0.1851~~
A	**daily exposure - pathways 1 - 7**	**3.2350**	**2.4918**	**2.0617**	**1.6289**	**1.4491**	**1.5965**	**1.6503**	**0.9495**
B	**daily exposure - pathways 2 - 7**	**0.4368**	**0.4321**	**0.4400**	**0.4352**	**0.2289**	**0.6983**	**0.1923**	**0.1911**

max	estimated based on maximum concentration detected
avg	estimated based on average concentration detected
na	not applicable - screened out during chemical screening

Arsenic – Scenario A: Assuming the water from the river system is used for drinking water, CRL values of 1.6 x 10^{-3} to 2.4 x 10^{-3} have been calculated for the average and average of the maximum water concentrations detected, respectively. These values are greater than the lower limit of the *de minimus* risk levels, and they are approximately 2 times greater than the plausible maximum CRL (1.4 x 10^{-3}) for the TOR. This result is consistent with the result described above for non-cancer effects and indicates that residents in Study Area B may be exposed to levels of arsenic greater than the TOR.

Arsenic – Scenario B: Assuming that water from the river system is not used for drinking water purposes, CRL values of 3.3 x 10^{-4} and 4.0 x 10^{-4} have been calculated for average and average of the maximum concentrations detected, respectively. These values are approximately 3 to 4 times greater than the lower limit of the *de minimus* risk levels. However, they are similar to the CRL values estimated for the TOR. For example, the 50th percentile CRL value for the TOR is 5.4 x 10^{-4}. These results indicate that the potential cancer risks to area residents are not significantly different than the TOR. However, area residents would also be exposed to arsenic form food and, as described above, approximately 75 percent of the total exposure to arsenic by the TOR are derived from food.

Based on the estimated ER values and CRL estimates, residents from Study Area B are unlikely to be exposed to higher levels of arsenic than the TOR unless water from the river system is consumed for drinking water.

3.4.3.5 Stoco Lake (Study Area C)

The estimated exposure for the child receptor (age 5 to 11 years) to the priority metals present in Study Area C is given in Table 3.4-12, and the calculated ERs based on these exposure estimates are given in Table 3.4-13. The key findings are summarized below.

Chromium, Cadmium, Cobalt, Lead, and Nickel: These metals all had exposure ratios less than 1 under all model scenarios, and therefore, are not expected to represent a health risk to users of the river system in Study Area C.

Table 3.4-12

Estimated Exposures for Child Receptor: Study Area C Non-Cancer Endpoints

		Estimated Exposure (ug/kg/day)											
Exposure	Exposure Pathway	arsenic		cadmium		chromium		cobalt		lead		nickel	
Pathway	Description	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg
1	consumption of water	na	na	na	na	na	na	na	na	na	na	na	na
2	accidental ingestion of water	na	na	na	na	na	na	na	na	na	na	na	na
3	dermal contact - swimming	na	na	na	na	na	na	na	na	na	na	na	na
4	dermal contact - bathing/shower	na	na	na	na	na	na	na	na	na	na	na	na
5	accidental ingestion of sediment	0.012	0.012	na	na	na	na	0.040	0.040	na	na	0.001	0.001
6	dermal contact with sediment	0.006	0.006	na	na	na	na	0.000	0.000	na	na	0.001	0.001
7	ingestion of fish	0.069	0.069	0.001	0.001	na	na	na	na	0.055	0.055	0.000	0.000
A	**total exposure - pathways 1 - 7**	**0.086**	**0.086**	**0.001**	**0.001**	**0.000**	**0.000**	**0.040**	**0.040**	**0.055**	**0.055**	**0.002**	**0.002**
B	**total exposure - pathways 2 - 7**	**0.086**	**0.086**	**0.001**	**0.001**	**0.000**	**0.000**	**0.040**	**0.040**	**0.055**	**0.055**	**0.00**	**0.002**

max	estimated based on the ten year average of the annual maximum concentration detected
avg	estimated based on average concentration detected
na	not applicable - screened out during chemical screening

Table 3.4-13
Calculated Exposure Ratios for Child Receptor: Study Area C Non-Cancer Endpoints

	Exposure Ratios											
Exposure Pathway	arsenic		cadmium		chromium		cobalt		lead		nickel	
	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg
Reference Dose (RfD)	0.30	0.30	1.00	1.00	3.00	3.00	60.00	60.00	1.85	1.85	1.30	1.30
Exposure Pathways 1 - 7	0.29	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
776 Exposure Pathways 2 - 7	0.29	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

max	estimated based on the ten year average of the annual maximum concentration detected
avg	estimated based on average concentration detected
▨	exposure ratio greater than 1

Arsenic: All ER values were less than one. These results indicate residents in Study Area C are unlikely to have higher arsenic exposure levels than the TOR.

Carcinogens

The estimated daily exposures to arsenic for each life stage exposed to arsenic present in Study Area C are given in Table 3.4-14. The LADD for each scenario and the estimated excess cancer risk associated with this exposure is given in Table 3.4-8. The key findings are discussed below.

The estimated cancer risks due to arsenic range from 5.8×10^{-5} to 5.4×10^{-4} under all exposure scenarios and water concentrations. Even the highest CRL value is equal to the 50th percentile CRL value for the TOR (5.4×10^{-4}). Only under exposure pathway Scenario A and assuming maximum average concentrations in water do the risks exceed typical *de minimus* or negligible cancer risk levels (i.e., 1×10^{-6} to 1×10^{-4}).

Based on the above results, arsenic in Study Area C does not represent a health risk to area residents.

3.4.3.6 Moira River Downstream of Stoco Lake (Study Area D)

Non-Carcinogens

The estimated exposure for the child receptor (age 5 to 11 years) to the priority metals present in Study Area D is given in Table 3.4-15, and the calculated ERs based on these exposure estimates are given in Table 3.4-16. The key findings are summarized below.

Arsenic had the highest ER value at 0.57. All other metals had ER values less than 0.25. These results indicate that none of the substances examined in this assessment represent a potential health risk to users of the river system in Study Area D.

Table 3.4-14
Estimated Daily Exposure to Arsenic for Each Life Stage: Study Area C Cancer Effects

		Estimated Daily Exposure (ug/kg/day)							
		Preschool Child (7 mo. - 4 yrs)		Child (5 - 11 yrs)		Adolescent (12 - 19)		Adult	
Exposure Pathway	Exposure Pathway Description	max	avg	max	avg	max	avg	max	avg
1	consumption of water	0.6413	na	0.3716	na	0.2796	na	0.3341	na
2	accidental ingestion of water	0.0039	na	0.0039	na	0.0011	na	0.0009	na
3	dermal contact - swimming	0.0000	na	0.0000	na	0.0000	na	0.0000	na
4	dermal contact - bathing/shower	0.0002	na	0.0002	na	0.0002	na	0.0001	na
5	accidental ingestion of sediment	0.0093	0.0093	0.0094	0.0094	0.0013	0.0013	0.0011	0.0011
6	dermal contact with sediment	0.0026	0.0026	0.0044	0.0044	0.0011	0.0011	0.0003	0.0003
7	ingestion of fish	0.0685	0.0685	0.0685	0.0685	0.0378	0.0378	0.0319	0.0319
A	**daily exposure - pathways 1 - 7**	**0.7259**	**0.0805**	**0.4581**	**0.0823**	**0.3210**	**0.0401**	**0.3685**	**0.0333**
B	**daily exposure - pathways 2 - 7**	**0.0846**	**0.0805**	**0.0864**	**0.0823**	**0.0414**	**0.0401**	**0.0344**	**0.0333**

max	estimated based on maximum concentration detected
avg	estimated based on average concentration detected
na	not applicable - screened out during chemical screening

Table 3.4-15
Estimated Exposures for Child Receptor: Study Area D Non-Cancer Endpoints

Exposure Pathway	Exposure Pathway Description	Estimated Exposure (ug/kg/day)											
		arsenic		cadmium		chromium		cobalt		lead		nickel	
		max	avg	max	avg	max	avg	max	avg	max	avg	max	avg
1	consumption of water	na	na	na	na	na	na	na	na	na	na	na	na
2	accidental ingestion of water	na	na	na	na	na	na	na	na	na	na	na	na
3	dermal contact - swimming	na	na	na	na	na	na	na	na	na	na	na	na
4	dermal contact - bathing/shower	na	na	na	na	na	na	na	na	na	na	na	na
5	accidental ingestion of sediment	0.043	0.043	na	na	na	na	na	na	na	na	na	na
6	dermal contact with sediment	0.020	0.020	na	na	na	na	na	na	na	na	na	na
7	ingestion of fish	~~0.108~~	~~0.108~~	~~0.000~~	~~0.000~~	~~na~~	~~na~~	~~na~~	~~na~~	~~0.020~~	~~0.020~~	~~0.000~~	~~0.000~~
A	**total exposure - pathways 1 - 7**	**0.171**	**0.171**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.020**	**0.020**	**0.000**	**0.000**
B	**total exposure - pathways 2 - 7**	**0.171**	**0.171**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.020**	**0.020**	**0.000**	**0.000**

max	estimated based on the ten year average of the annual maximum concentration detected
avg	estimated based on average concentration detected
na	not applicable - screened out during chemical screening

Table 3.4-16
Calculated Exposure Ratios for Child Receptor: Study Area D Non-Cancer Endpoints

	Exposure Ratios											
Exposure Pathway	arsenic		cadmium		chromium		cobalt		lead		nickel	
	max	avg	max	avg	max	avg	max	avg	max	avg	max	avg
Reference Dose (RfD)	0.30	0.30	1.00	1.00	3.00	3.00	60.00	60.00	1.85	1.85	1.30	1.30
Exposure Pathways 1 - 6	0.57	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exposure Pathways 2 - 6	0.57	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

max	estimated based on the ten year average of the annual maximum concentration detected
avg	estimated based on average concentration detected
▨	exposure ratio greater than 1

Table 3.4-17
Estimated Daily Exposure to Arsenic for Each Life Stage: Study Area D Cancer Effects

		Estimated Daily Exposure (ug/kg/day)							
Exposure	Exposure Pathway	Preschool Child (7 mo. - 4 yrs)		Child (5 - 11 yrs)		Adolescent (12 - 19)		Adult	
Pathway	Description	max	avg	max	avg	max	avg	max	avg
1	consumption of water	na	na	na	na	na	na	na	na
2	accidental ingestion of water	na	na	na	na	na	na	na	na
3	dermal contact - swimming	na	na	na	na	na	na	na	na
4	dermal contact - bathing/shower	na	na	na	na	na	na	na	na
5	accidental ingestion of sediment	0.0078	0.0078	0.0078	0.0078	0.0011	0.0011	0.0009	0.0009
6	dermal contact with sediment	0.0022	0.0022	0.0037	0.0037	0.0009	0.0009	0.0003	0.0003
7	ingestion of fish	0.1083	0.1083	0.1083	0.1083	0.0597	0.0597	0.0504	0.0504
A	**daily exposure - pathways 1 - 7**	**0.1182**	**0.1182**	**0.1197**	**0.1197**	**0.0616**	**0.0616**	**0.0516**	**0.0516**
B	**daily exposure - pathways 2 - 7**	**0.1182**	**0.1182**	**0.1197**	**0.1197**	**0.0616**	**0.0616**	**0.0516**	**0.0516**

max	estimated based on maximum concentration detected
avg	estimated based on average concentration detected
na	not applicable - screened out during chemical screening

Carcinogens

The estimated daily exposure to arsenic for each life stage exposed to arsenic present in Study Area D are given in Table 3.4-17. The LADD for each scenario and the estimated excess cancer risk associated with this exposure is given in Table 3.4-8.

The estimated cancer risks due to arsenic in Study Area D is 8.8×10^{-5}. This is within the range of *de minimus* or negligible cancer risk levels (i.e., 1×10^{-6} to 1×10^{-4}).

Based on the above results, arsenic in Study Area D does not represent a potential risk to human health.

3.4.3.7 Uncertainty Analysis

In a risk assessment, the doses and benchmarks are estimated from the available information about how exposure might take place and the doses that cause effects. There is always uncertainty associated with these estimations, depending on the quality, quantity and variability associated with the available information. When information is uncertain, it is standard practice in a risk assessment to make assumptions that are biased towards safety, so that even if there is uncertainty, human health will still be protected. Every effort is made to ensure that assumptions are specific to the site being evaluated.

There are several layers of safety applied in this PQRA. For instance, the sediment exposure pathway models assumed that an individual is exposed to sediments 120 times per year (60 days x 2 events per day). There were limited data on shallow water sediment concentrations and activity use patterns for residents in the study areas. In Study Area A, the areas of sediment accumulation were localized and where observed, consisted of fine-grained materials deposited in shallow backwater areas (see Section 2.2.3). In general, these areas did not appear attractive for recreational use because of the fine muddy nature of the bottom sediments and the fact the water is too shallow for swimming. Also, depending on the river flow and sediment deposition dynamics, exposure to sediments in at least some portions of the river is unlikely. Taken together, it is probable that the potential sediment exposure has been overestimated.

The exact amount of time a child spends outside in contact with sediments was uncertain because it varies with the weather, other activities of the child's family, and the child's own preferences. The risk assessment assumed, as a worst case, that a child would spend time in contact with water and sediments every day for 60 days. This is conservative since children would be spending time in other activities as well.

The maximum and average concentrations of each metal in water were used to help address the uncertainty associated with differences in chemical concentrations in water. Comparison of the exposure estimates for the maximum versus average water concentrations revealed that differences in water concentrations were much more important when it is assumed that the river water is used as a source of drinking water (i.e., Scenario A).

The metal concentrations in sediment were uncertain because the information was based on a limited number of samples at one time period and/or there was considerable variability in concentrations of metals between samples in the area. In this case, a layer of safety was added by calculating exposure based on the maximum observed metal concentration, even if this was only in one very small area.

To address the uncertainty associated with differences in receptor water usage characteristics, two different exposure pathway scenarios were evaluated. Scenario A assumed that river water is used for drinking and cooking, whereas Scenario B assumed that the river is not used for drinking or cooking. Both scenarios consider consumption of fish from, and recreational uses of, the Moira River system.

There was also uncertainty associated with estimating benchmark doses. Benchmark doses are based on toxicity information available from government databases and published scientific literature. The majority of toxicity information comes from the results of experiments with laboratory animals. Some additional information on human health effects is also available for some substances where cases of workplace exposures and associated health effects have been documented. There is some uncertainty in extrapolating from animal studies and workplace case studies to the possible effects that may result from exposure to arsenic in sediments in Study Area

A. To add a layer of safety, it is standard practice in a risk assessment to assume that people are more sensitive to the toxic effects of a chemical than laboratory animals. Therefore, the benchmark dose for human health is set at a much lower level than the animal benchmark (typically 100 to 1000 times lower). This large margin of safety ensures that minor exceedances of these benchmark doses will not cause adverse health effects.

Because of all of the layers of safety incorporated into the calculation of an ER, values that are at or marginally greater than one do not indicate that adverse effects are occurring or are likely to occur. Minor exceedances of the benchmark (resulting in ER values slightly above one) are within the layers of safety incorporated into the risk assessment.

There were some sources of uncertainty that had an unpredictable effect on the level of conservatism of the assessment. In using methodology consistent with Cantox (1999), this assessment assumed that individuals would be exposed only to inorganic arsenic, which has in the past been considered more toxic than organic forms. However, in recent years, a number of studies suggest that some organic arsenic species may be more toxic than some inorganic forms (for example, Aposhian *et al.* 2000; Petrick *et al.* 2000). Inorganic arsenic in groundwater and surface water can be reduced (methylated) by micro-organisms, albeit to a limited extent. Therefore, it is likely that a portion of the arsenic measured in sediment and water samples along the river system is present in the organic form. The potential impact of this uncertainty cannot be determined at this time, as the identification and study or toxic organic arsenic species is a relatively new area of study for this metalloid.

Exposure estimates were adjusted for bioavailability using literature information (tabulated in Table 3.4-3). The bioavailability factors selected (tabulated in Table 3.4-4) represent the best available. However, it is difficult to accurately determine bioavailability in humans under various conditions. Complicating this issue is the complex chemistry of arsenic, which may occur in many inorganic and organic forms, and which may be converted by biological or physicochemical processes into other species.

The screening procedure used to identify substances of potential concern involved comparing chemical concentrations in samples from the Moira River system with corresponding concentrations in similar samples collected from reference locations. It is possible that an unusually high reference value (due, for example, to specific local geology) could lead to a substance being inadvertently eliminated from further evaluation. However, this is considered unlikely, as reference locations and sample types were selected to be similar to locations along the Moira River system.

On balance, the PQRA was conservative, with several layers of safety built into the analysis. Therefore, elimination of concern about particular metals or exposure pathways was possible and defensible. This was because if estimated exposures were less than benchmark values even with several layers of safety, then it could be concluded that there was no risk to human health. Furthermore, because of the use of several layers of safety, identification of arsenic as a concern in Study Area A does not imply that there is, in fact, a significant risk to human health. Rather, the focus provided by the PQRA called attention to issues in Study Area A that required additional study and/or risk management.

3.4.3.8 Multimedia Approach

Given the scope of work, a multimedia assessment has not been conducted as part of this PQRA. It is recognized that there are other significant sources of exposure to these metals such as diet, as outlined in the environmental health risk assessment conducted for the Village of Deloro (CanTox, 1999). To account for other sources of exposure, it is often assumed that 20 percent of the total allowable (safe) intake is apportioned to any single source (i.e., the river system). Examination of the ERs reveals that with the exception of arsenic, most ER values are less than 0.2. This indicates that a multimedia approach is unlikely to have changed the findings of this study.

3.5 Conclusions

This PQRA identified how humans may be exposed to substances released by the Deloro Mine Site and which are present in the Moira River system. It was a semi-quantitative screening level assessment that was used to identify and eliminate the substances and exposure pathways not requiring further assessment, as well as to identify exposure scenarios requiring further evaluation. This assessment is not designed to quantify health impacts.

No findings in this report should be taken to confirm that adverse health impacts are occurring among river system users.

Cadmium, chromium, cobalt, lead, and nickel do not represent a potential health risk in any study area and further assessment of the potential health risks posed by these metals is not required.

Arsenic in Study Areas C and D is not expected to lead to significantly elevated exposures compared to the TOR, and further assessment of the potential health risks posed by this substance in these areas is not warranted.

The PQRA showed that residents of Study Areas A and B (from the Deloro Mine Site to the outlet of Moira Lake) would have greater estimated levels of exposure to arsenic than the TOR under the conditions assumed in the assessment. Use of water from the river system for drinking water is the most significant pathway of exposure to arsenic. The reminder issued by the MOE and the Hastings and Prince Edward Counties Health Unit to residents of Study Areas A and B advising them not to drink untreated surface water was, and continues to be, appropriate. The reminder is not only appropriate because of concerns about arsenic, but also because of the risk of exposure to pathogens in untreated water.

The section of the river above Moira Lake (Study Area A) is not well suited for in-water recreational activities and has only a limited number of residences. However, recreational use of this section of the river system may be an important exposure pathway, at least for some individuals. The amount of exposure through this pathway, both in absolute terms and relative to total arsenic exposure, requires further study. (This study was completed and is presented in Appendix X).

Based on the findings of MOE (1999), metals of concern in fish fillets from the Moira River system are at concentrations below those that could require restrictions of fish consumption. CanTox (1999), who reported that levels of arsenic in fish considered in the Deloro Village risk assessment study were consistent with those observed elsewhere in Ontario, supports this. No further assessment of this pathway (i.e., ingestion of fish) is required.

It should be noted that fish consumption advice published in MOE's "Guide to Eating Ontario Sport Fish 1999-2000" includes some restriction on certain sizes of certain species of sport fish in Moira Lake, Stoco Lake and the two reference lakes, Consecon Lake and Round Lake. Although a range of metals and other chemicals was measured in fish sampled collected from each of the lakes, only mercury warranted consumption restrictions. Consumption restrictions based on mercury are widespread throughout Ontario's lakes and rivers, due in part to natural geological presence of mercury and the likelihood of its accumulation in the flesh of larger predatory sport fish. Mercury is not related to discharges from the Deloro Mine Site.

3.6 References

Ariza, M., Bijur, G. and Williams, M. 1999. Environmental metal pollutants, reactive oxygen intermediates and geotoxicity. Kluwer Academic Publishers, Boston.

Aposhian, V.H., Gurzau, E.S., Le, X.C., Gurzau, A., Healy, S.M., Lu, X., Ma, M., Yip, L., Zakharyan, R.A., Maiorino, R.M., Dart, R.C., Tirus, M.G., Gonzalez-Ramirez, D., Morgan, D.L., Avram, D., Aposhian, M.M. 2000. Occurrence of monomethylarsenous acid (MMA III) in urine of humans exposed to inorganic arsenic. Chem. Res. Toxicol. 165:74-83

ATSDR. 1993. Toxicological profile arsenic. Agency for Toxic Substances and Disease Registry, April 1993.

ATSDR. 1993. Toxicological profile cadmium. Agency for Toxic Substances and Disease Registry, April 1993.

ATSDR. 1993. Toxicological profile chromium. Agency for Toxic Substances and Disease Registry, April 1993.

ATSDR. 1993. Toxicological profile lead. Agency for Toxic Substances and Disease Registry, April 1993.

Cantox. 1999. Deloro Village exposure assessment and health risk characterization for arsenic and other metals. Prepared by Cantox Environmental Inc. December, 1999.

CCME. 1995. Canadian Council of Ministers of the Environment. Canadian water quality guidelines (Revised December, 1995).

Goyer, R. Toxic effect of metals. C. Klaassen ed. Casarett & Doull's toxicology the basic science of poison. 5th ed. McGraw-Hill; 1996.

MOE. 1999. Guide to Eating Ontario Sport Fish 1999-2000. Ministry of the Environment. Twentieth Edition, Revised.

Ontario Ministry of Environment (MOE). 1997. Guideline for use at contaminated sites in Ontario. Ministry of the Environment and Energy (MOE). Revised February, 1997. Queens Printer for Ontario, Toronto, ON.

Ontario Ministry of Environment (MOE). 1996. Guidance on site specific risk assessment for use at contaminated sites in Ontario. Queens Printer for Ontario, Toronto, ON.

Ontario Ministry of Environment and Energy (MOE). 1999a. Water management policies: guidelines provincial water quality objectives. Queen's Printer for Ontario, Toronto, ON.

Ontario Ministry of Environment and Energy (MOE). 1999b. Guideline for use at contaminated sites in Ontario. Queen's Printer for Ontario, Toronto, ON.

Petrick, J.S., Ayela-Fiero, F., Cullen, W.R., Carter, D.E., Aposhian, H.V. 2000.

Monomethylarsenous acid (MMA III) is more toxic than arsenite in Chang human hepatocytes. Toxicol. Appl. Pharmacol. 163:203-20

4. PREDICTIVE WATER AND SEDIMENT QUALITY MODEL

4.1 Objective

The objective of this component was to construct a water and sediment quality model to assess the level of cleanup required at the Deloro Mine Site for downstream arsenic, cobalt and nickel concentrations to reach, or fall below, provincial water and sediment quality objectives for the protection of aquatic life. In this exercise, the interim provincial water quality objective (PWQO) of 5 μg/L (MOE 1999) was used for arsenic because the MOE has stated that one of the objectives of the final cleanup plan for the Deloro Mine Site is to meet this interim PWQO.

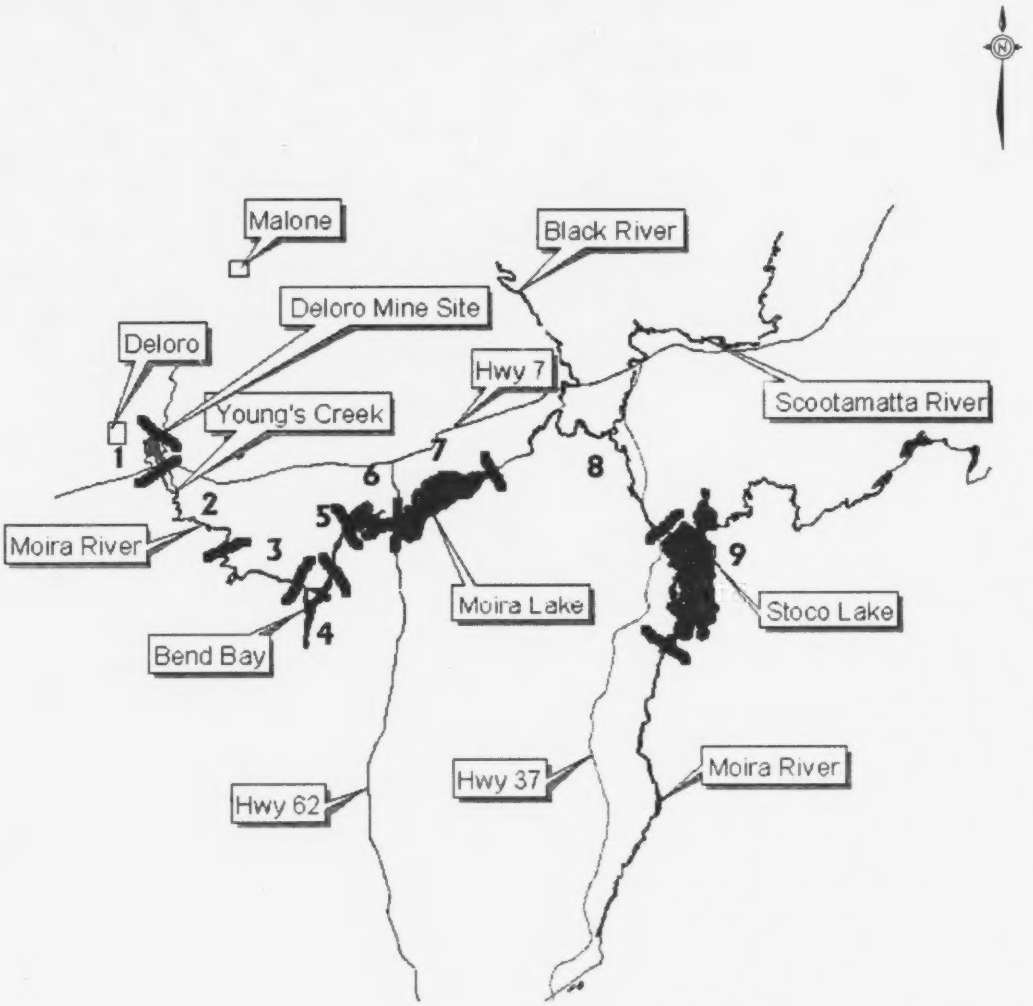
4.2 Scope

The Moira River Model (MRM) was built to simulate long-term water and sediment quality in the Moira River system between the Deloro Mine Site and the outlet of Stoco Lake. The model was based on average, long-term monthly water flows. The model incorporated sediment - water interaction and was calibrated to reflect general, long-term, water quality trends observed over the last 10 years. As such, the model may not adequately reflect the effects of short-term, sporadic events, such as flooding events, dry spells, or the effects of spring and fall turnover in lakes. However, the model included all of the most important processes that control long-term average metal concentrations in the Moira River system. The model was developed as a decision tool, and predictions are meant to serve as general indicators of the response of the Moira River system to future cleanup actions at the Deloro Mine Site.

4.3 Approach

The Moira River system between the Deloro Mine Site and the outlet of Stoco Lake was divided into nine model segments (Figure 4.3-1):

- Deloro Mine Site to Young's Creek;
- Young's Creek to half way to Bend Bay;
- Remaining distance to Bend Bay;
- Bend Bay;


N
Malone
Black River
Deloro Mine Site
Deloro
Hwy 7
Young's Creek
Scootamatta River
1
2
3
4
5
6
7
8
9
Moira River
Moira Lake
Stoco Lake
Bend Bay
Hwy 62
Hwy 37
Moira River

REFERENCE
BASE MAP PROVIDED BY GIS GOLDER MISSISSAUGA

SCHEMATIC ONLY
NOT TO SCALE

Golder Associates

RIVER SEGMENTS FOR WATER AND SEDIMENT QUALITY MODEL

DRAWN: TVS	APPROVED:	DATE: 16 Aug. 2000	
PROJECT: 991-1358. 8200		FIGURE: **4.3-1**	

Revision No. 01

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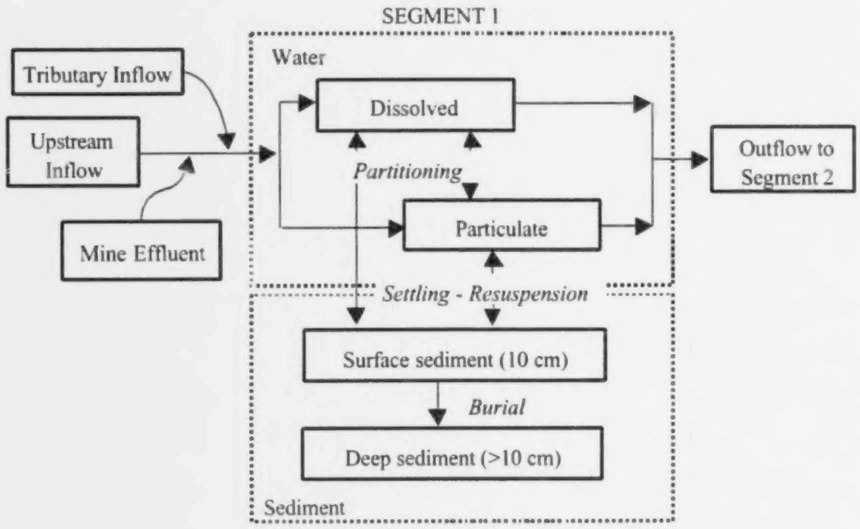
- Bend Bay to West Moira Lake;
- West Moira Lake;
- East Moira Lake;
- East Moira Lake to Stoco Lake; and
- Stoco Lake.

The MRM was built using STELLA software (HPS 1997). Each model segment incorporates advective transport, chemical partitioning, sediment deposition and resuspension, sediment bioturbation and sediment burial (Figure 4.3-2). The MRM was calibrated using historical water flow and water quality data and results from recent sediment sampling (as described in Section 2.2). Calibration also included adapting partition, deposition, burial and resuspension rates taken from relevant, available literature. The calibrated MRM was then used to determine the level of cleanup required at the Deloro Mine Site for downstream arsenic, cobalt and nickel concentrations to reach, or fall below, provincial water quality objectives (PWQOs) for the protection of aquatic life.

Arsenic, cobalt and nickel were selected from the metals of concern discussed in Sections 2.1 and 2.2, because:

- arsenic and cobalt concentrations consistently exceeded PWQOs throughout the Moira River system; and,
- other heavy metals, including silver, copper and lead, will exhibit similar behavioural patterns as one of the chosen substances (i.e., in-stream concentrations will increase or decrease in the same fashion as predicted for one of the modelled substances).

Figure 4.3-2
Illustration of the Pathways Included in the Moira River Model


SEGMENT 1
Water
Tributary Inflow
Upstream Inflow
Mine Effluent
Dissolved
Partitioning
Particulate
Outflow to Segment 2
Settling - Resuspension
Surface sediment (10 cm)
Burial
Deep sediment (>10 cm)
Sediment

4.4 Model Construction and Calibration

The general set-up of the MRM is described in Section 4.4.1, followed by a discussion of how water flows and the movement of suspended sediments were incorporated into the MRM (Sections 4.4.2 and 4.4.3, respectively). Section 4.4.4 describes the chemical component of the MRM in greater detail and the general process used to calibrate the model for arsenic, cobalt and nickel.

4.4.1 Model Set-up

The physical dimensions of each of the nine model segments are summarized in Table 4.4-1. Each model segment was sub-divided into three compartments: water, surface sediment (the uppermost 10 cm of the sediment profile) and deep sediment (below a sediment depth of 10 cm). The water compartment in each model segment was assumed to be completely mixed, an assumption supported by the absence of thermal stratification in Moira and Stoco lakes (Section 2.1). Surface sediments were also assumed to be completely mixed to a depth of 10 cm to account for bioturbation by benthic invertebrates (Diamond 1995, Bosworth and Thibodeaux

1990). The deep sediments do not mix in the model; they act as a sink for buried sediment and associated heavy metals (Figure 4.3-2).

Table 4.4-1
The Physical Dimensions of Each Model Segment

Segment		Depth	Width	Surface Area	Volume	
Number	Name	(m)	(m)	(m^2)	(m^3)	Source
1	Deloro to Young's Creek	1	30	114 000	114 000	Based on data from Section 2.3
2	Young's Creek to half way to Bend Bay	1	30	186 000	186 000	Based on data from Section 2.3
3	Remaining distance to Bend Bay	1	30	214 500	214 500	Based on data from Section 2.3
4	Bend Bay	1	-	210 000	210 000	Diamond (1995)
5	Bend Bay to West Moira Lake	1	30	102 000	102 000	Based on data from Section 2.3
6	West Moira Lake	3.5	-	2 160 000	7 560 000	Diamond (1995)
7	East Moira Lake (EML)	4	-	6 110 000	24 440 000	Diamond (1995)
8	EML to Stoco Lake	2	50	890 000	1 780 000	Based on data from Section 2.3
9	Stoco Lake	4	-	5 630 000	22 520 000	MOE (1972, 1974)

The concentration of arsenic, cobalt or nickel in the water compartment of a given model segment was calculated based on the following relationship:

concentration at time "*t*" = mass at time "*t*" / water volume at time "*t*" (1)

where,

mass at time "*t*" = mass at time "*t-1*" + the change in mass from time "*t-1*" to time "*t*" (Δm) (2)

and,

Δm = mass in - mass out - mass settled + mass resuspended + mass diffused (3)

Similarly, arsenic, cobalt or nickel levels in the surface sediments of a given model segment were calculated based on the same relationship where:

concentration at time "*t*" = mass at time "*t*" / sediment volume at time "*t*" (4)

and,

Δm = mass settled - mass resuspended - mass diffused - mass buried (5)

The chemical mass moving in and out of each model segment was controlled by water flow. Sediment interactions (i.e., settling, resuspension and burial) were controlled, in part, by the rates at which sediments settled, became resuspended or were buried. Sediment settling, resuspension and burial rates operated independently from the chemical being modelled (i.e., they were the same for arsenic, cobalt and nickel).

4.4.2 Water Flows

Source Data

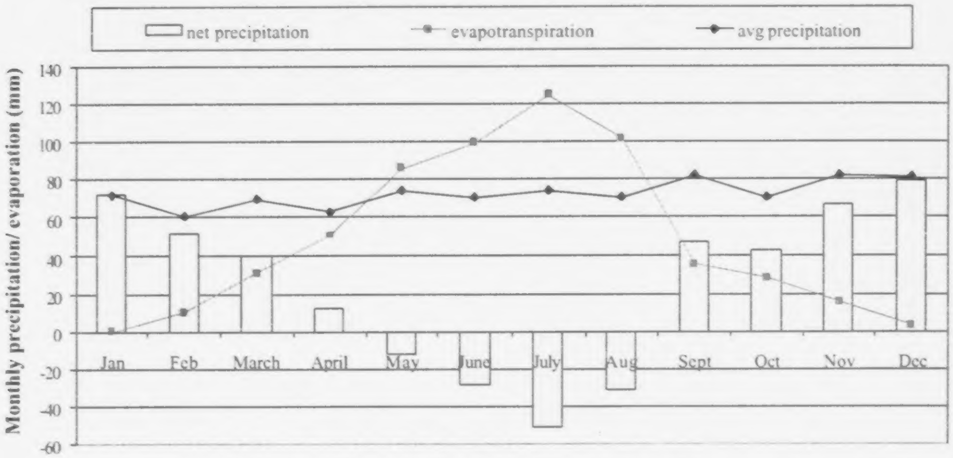
The sources of the water flow data used in the MRM are given in Table 4.4-2. Monthly precipitation data from 1925 to 1990 were taken from an Environment Canada monitoring station located in Tweed, Ontario (Environment Canada 1994). Estimates of monthly evapotranspiration rates were derived from MOE (1974). Average, monthly net precipitation rates used in the MRM are illustrated in Figure 4.4-1.

Table 4.4-2
Source of Water Flow Data Used to Build the Moira River Model

Waterbody	Station Number	Data Available	Source[a]
Moira River - at Deloro	02HL005	Continuous monthly data from 1966 to 1998	1, 2
- at Thomasburg	02HL104	Monthly data from 1969 to 1970	1
- at Foxboro	02HL001	Continuous monthly data from 1965 to 1998	1, 2
Young's Creek	-	Estimate of average annual flow	3
Black River	02HL003	Continuous monthly data from 1955 to 1995	1
Skootamatta River	02HL004	Continuous monthly data from 1955 to 1995	1
Clare River	02HL102	Monthly data from 1968 to 1977	1

[a] 1 = Environment Canada (1999), 2 = WSC (2000) and 3 = CG&S (1999).

Figure 4.4-1
Average, Monthly Net Precipitation Rates Used in the Moira River Model



Water Balance

The long-term water balance for the Moira River system was constructed based on the assumption that the volume of water held within each model segment was constant over time. Therefore,

segment outflow = upstream inflow + tributary inflow + net precipitation (6)

Tributaries included in the model were: the Black and Skootamatta rivers (discharging to the Moira River between Moira and Stoco lakes); the Clare River (discharging to Stoco Lake); Young's Creek (discharging to the Moira River downstream of Highway 7); and, Madoc Creek (discharging to West Moira Lake).

Long-term, average monthly flow rates were calculated for the Black, Skootamatta and Clare rivers and for the Moira River at Deloro. For Young's Creek, the average annual flow rate calculated by CG&S (1999) was equivalent to 0.2% of the long-term, average annual flow rate observed in the Moira River at Deloro, so monthly flows in Young's Creek were assumed to be equal to 0.2% of monthly flows observed in the Moira River at Deloro. Similarly, Diamond (1995) noted that flows in Madoc Creek, a small tributary to West Moira Lake, were approximately equal to 10% of the inflow from the Moira River, so monthly flows in Madoc Creek were assumed to be equal to 10% of monthly flows in the Moira River at the inlet to West Moira Lake.

Net precipitation, as defined in Figure 4.4-1, was included in the Bend Bay, West Moira Lake, East Moira Lake and Stoco Lake model segments, but it was not included (i.e., set to zero) in the five river segments. It was assumed that evaporation and precipitation would only be significant in large open water areas with relatively still waters. The gain or loss of water through evaporation and precipitation represented a small fraction of the water flowing through each lake segment (Table 4.4-3), and the inclusion of net precipitation in the river segments would not substantially alter the conclusions of this study.

To calibrate the water balance, monthly outflows from the Stoco Lake model segment were compared to average monthly flow rates recorded at the Thomasburg monitoring station. Only two years worth of data were available from the Thomasburg monitoring station (Table 4.4-2). To increase the amount of data available for comparison, data from the Foxboro monitoring site were transformed using the following relationship:

$$Q_{Tx} = Q_{Fx} * ((Q_{Fa} - Q_{Ta}) / Q_{Fa}) \tag{7}$$

where: Q_{Tx} = monthly flow at Thomasburg in Year "x" (m^3/s)

Q_{Fx} = monthly flow at Foxboro in Year "x" (m^3/s)

Q_{Fa} = average monthly flow at Foxboro between 1969 and 1970 (m^3/s)

Q_{Ta} = average monthly flow at Thomasburg between 1969 and 1970 (m^3/s)

Stream flows in Clare River were adjusted until the outflow from Stoco Lake matched with the average monthly flow record developed for Thomasburg. The resulting water balance is summarized in Table 4.4-3.

Table 4.4-3
Water Flow Through The Moira River Model

Model Segment	Parameter	Month											
		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Deloro to Young's Creek	Upstream inflow (m^3/s)	3.5	3.0	7.7	14.3	5.2	1.7	0.6	0.3	0.6	1.3	3.5	4.2
	Outflow (m^3/s)	3.5	3.0	7.7	14.3	5.2	1.7	0.6	0.3	0.6	1.3	3.5	4.2
	Retention time (day)	0.4	0.4	0.2	0.1	0.3	0.8	2.3	4.7	2.1	1.0	0.4	0.3
Young's Creek to half way to Bend Bay	Upstream inflow (m^3/s)	3.5	3.0	7.7	14.3	5.2	1.7	0.6	0.3	0.6	1.3	3.5	4.2
	Young's Creek (m^3/s)	0.007	0.006	0.016	0.029	0.011	0.004	0.001	0.001	0.001	0.003	0.007	0.009
	Outflow (m^3/s)	3.5	3.0	7.7	14.3	5.3	1.8	0.6	0.3	0.6	1.3	3.5	4.2
	Retention time (day)	0.6	0.7	0.3	0.2	0.4	1.2	3.7	7.7	3.4	1.6	0.6	0.5
Remaining distance to Bend Bay	Upstream inflow (m^3/s)	3.5	3.0	7.7	14.3	5.3	1.8	0.6	0.3	0.6	1.3	3.5	4.2
	Outflow (m^3/s)	3.5	3.0	7.7	14.3	5.3	1.8	0.6	0.3	0.6	1.3	3.5	4.2
	Retention time (day)	0.7	0.8	0.3	0.2	0.5	1.4	4.3	8.8	3.9	1.9	0.7	0.6
Bend Bay	Upstream inflow (m^3/s)	3.5	3.0	7.7	14.3	5.3	1.8	0.6	0.3	0.6	1.3	3.5	4.2
	Net precipitation (m^3/s)	0.006	0.004	0.003	0.001	-0.001	-0.002	-0.004	-0.002	0.004	0.003	0.005	0.006
	Outflow (m^3/s)	3.5	3.0	7.7	14.3	5.3	1.7	0.6	0.3	0.6	1.3	3.5	4.2
	Retention time (day)	0.7	0.8	0.3	0.2	0.5	1.4	4.3	8.7	3.8	1.8	0.7	0.6
Bend Bay to West Moira Lake	Upstream inflow (m^3/s)	3.5	3.0	7.7	14.3	5.3	1.7	0.6	0.3	0.6	1.3	3.5	4.2
	Outflow (m^3/s)	3.5	3.0	7.7	14.3	5.3	1.7	0.6	0.3	0.6	1.3	3.5	4.2
	Retention time (day)	0.3	0.4	0.2	0.1	0.2	0.7	2.1	4.2	1.8	0.9	0.3	0.3

Model Segment	Parameter	Month											
		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
West Moira Lake	Upstream inflow (m^3/s)	3.5	3.0	7.7	14.3	5.3	1.7	0.6	0.3	0.6	1.3	3.5	4.2
	Madoc Creek (m^3/s)	0.35	0.30	0.77	1.43	0.53	0.17	0.06	0.03	0.06	0.13	0.35	0.42
	Net precipitation (m^3/s)	0.06	0.05	0.03	0.01	-0.01	-0.02	-0.04	-0.03	0.04	0.03	0.06	0.06
	Outflow (m^3/s)	4.0	3.4	8.6	15.7	5.8	1.9	0.6	0.3	0.7	1.5	3.9	4.7
	Retention time (day)	22	26	10	6	15	46	149	311	117	59	22	19
East Moira Lake (EML)	Upstream inflow (m^3/s)	4.0	3.4	8.6	15.7	5.8	1.9	0.6	0.3	0.7	1.5	3.9	4.7
	Net precipitation (m^3/s)	0.16	0.13	0.09	0.03	-0.03	-0.07	-0.11	-0.07	0.11	0.10	0.16	0.18
	Outflow (m^3/s)	4.1	3.5	8.6	15.8	5.7	1.8	0.5	0.2	0.9	1.6	4.1	4.8
	Retention time (day)	69	81	33	18	49	154	599	1346	331	178	70	58
EML to Stoco Lake	Upstream inflow (m^3/s)	4.1	3.5	8.6	15.8	5.7	1.8	0.5	0.2	0.9	1.6	4.1	4.8
	Black River (m^3/s)	4.4	3.6	9.3	17.7	7.3	2.8	1.4	1.3	1.4	1.9	4.3	5.4
	Skootamatta River (m^3/s)	7.6	7.0	15.3	30.0	12.5	4.1	1.5	1.0	1.5	3.1	6.9	9.1
	Outflow (m^3/s)	16.1	14.0	33.3	63.4	25.5	8.7	3.4	2.5	3.8	6.6	15.2	19.4
	Retention time (day)	1.3	1.5	0.6	0.3	0.8	2.4	6.1	8.2	5.5	3.1	1.4	1.1
Stoco Lake	Upstream inflow (m^3/s)	16.1	14.0	33.3	63.4	25.5	8.7	3.4	2.5	3.8	6.6	15.2	19.4
	Clare River (m^3/s)	9.0	8.9	18.7	33.1	13.8	2.5	0.4	0.3	0.2	0.3	1.3	2.4
	Net precipitation (m^3/s)	0.15	0.12	0.08	0.03	-0.03	-0.06	-0.11	-0.07	0.10	0.09	0.15	0.17
	Outflow (m^3/s)	25.3	23.1	52.1	96.6	39.3	11.1	3.7	2.7	4.0	7.0	16.7	21.9
	Retention time (day)	10	11	5	3	7	24	71	95	65	37	16	12

4.4.3 Suspended Solids

Source Data

The turbidity and total suspended solids (TSS) data used to calibrate the MRM were obtained from a series of water quality sample stations maintained by the Ontario Ministry of the Environment (see Section 2.1). TSS monitoring has been limited to occasional sampling since 1998. Turbidity measurements are available from 1967 to the end of 1998. Using the available TSS information, a turbidity to TSS relationship was developed (Figure 4.4-2). Long-term, average annual turbidity levels were transformed into TSS concentrations using this relationship (Table 4.4-4). The resulting annual average TSS concentration for West Moira Lake (i.e., 3.9 mg/L) matched the annual average TSS concentration reported by Diamond (1995).

Figure 4.4-2
Total Suspended Solids Concentrations in the Moira River System as a Function of Turbidity

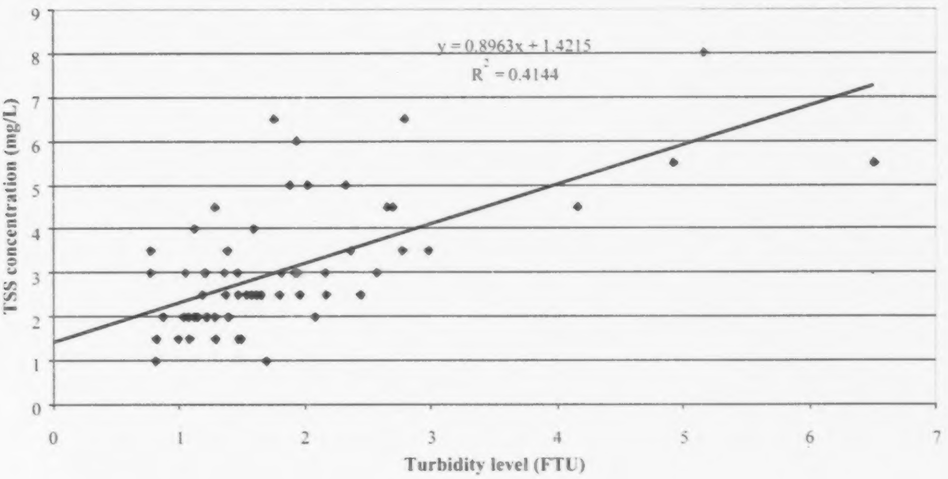


Table 4.4-4
Average Annual Total Suspended Solids and Turbidity Levels in the Moira River System

Waterbody	Turbidity (NTU)	Total Suspended Solids	
		Measured (mg/L)	Derived[a] (mg/L)
Moira River - upstream of Deloro	2.0	-	3.2
- upstream of Young's Creek	2.5	2.2	3.6
- between East Moira and Stoco lakes	2.3	2.4	3.5
Madoc Creek	3.4	2.8	4.5
Black River	1.9	2.2	3.2
Skootamatta River	2.2	2.2	3.4
Clare River	3.0	4.0	4.1
West Moira Lake	2.8	3.3	3.9
Stoco Lake	3.8	3.5	4.8

[a] Derived based on the relationship illustrated in Figure 4.4-2.
- = no data.

Sediment Balance

A sediment mass balance for the Moira River system was constructed based on the assumption that sediment density, sediment porosity, the depth of the surface sediment layer and the amount of suspended sediment contained within each model segment were constant over time. Under these conditions,

outgoing sediment mass = total incoming sediment mass - buried sediment mass

or

$$Q_{out}*[TSS] = Q_{in}*[TSS]_{in} - V_b*A*(1-\phi)*\rho*C \qquad (8)$$

where: Q_{out} = outflow from model segment "x" (m^3/s)
$[TSS]$ = TSS concentration in model segment "x" (mg/L)
Q_{in} = inflow to model segment "x" (m^3/s)
$[TSS]_{in}$ = TSS concentration in segment "x" inflow (mg/L)
V_b = burial velocity (mm/yr)
A = active sediment area (m^2)
ϕ = sediment porosity (unitless)
ρ = sediment density (kg/L)
C = unit conversion factor

Each parameter listed above was assigned a value based on available literature. The rate at which sediments were buried (V_b) and the initial TSS concentration in each segment ([TSS]) were then adjusted to achieve a balance. Values assigned to each parameter are listed in Table 4.4-5, and the resulting sediment balance is summarized in Table 4.4-6.

Table 4.4-5
Values Used to Achieve a Sediment Balance for the Moira River System

Model Segment	Sediment		TSS		Active Sediment Area[a] (%)	Burial Velocity	
	Density (kg/L)	Porosity (unitless)	Initial (mg/L)	Final (mg/L)		Initial (mm/yr)	Final (mm/yr)
Deloro to Young's Creek	2.2[b]	0.98[cd]	3.6[e]	3.6	20[f]	0.236[f]	0.205
Young's Creek to half way to Bend Bay			3.6[f]	3.6	20[f]	0.236[f]	0.207
Remaining distance to Bend Bay			3.6[f]	3.6	20[f]	0.236[f]	0.218
Bend Bay			3.5[b]	3.5	80[b]	1.180[f]	1.314
Bend Bay to West Moira Lake			3.5[f]	3.5	20[f]	0.236[f]	0.202
West Moira Lake			3.9[b]	3.1	33[b]	2.360[c]	2.054
East Moira Lake (EML)			3.9[b]	2.0	33[b]	3.530[d]	1.618
EML to Stoco Lake			3.5[e]	3.0	25[f]	1.765[f]	1.811
Stoco Lake			4.8[e]	2.9	33[f]	3.530[f]	3.524

[a] Active sediment area = fraction of bottom area where sediment accumulates.
[b] Based on information from Diamond (1995).
[c] Based on information from Mudroch and Capobianco (1980).
[d] Based on information from Cornett *et al.* (1987).
[e] Based on information in Table 4.4-4.
[f] Assumed value based on the characteristics of the other model segments.

Sediment Settling and Resuspension

For sediment density, sediment porosity and the depth of the surface sediment layer to be constant over time within each model segment,

resuspended sediment mass = settled sediment mass - buried sediment mass

or,

$$V_r*A*(1-\phi)*\rho = V_s*A*[TSS]*C - V_b*A*(1-\phi)*\rho \tag{9}$$

where: V_r = resuspension velocity (mm/yr)

Table 4.4-6
Sediment Balance for the Moira River System

Model Segment	Parameter	Month (kg/month)											
		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Deloro to Young's Creek	Upstream sediment	34018	26411	74300	132694	50946	16468	5581	2715	5938	12705	32562	40213
	Buried sediment	16	12	35	63	24	8	3	1	3	6	15	19
	Outgoing sediment	34002	26399	74265	132631	50922	16460	5578	2714	5936	12699	32546	40194
Young's Creek to half way to Bend Bay	Upstream sediment	34002	26399	74265	132631	50922	16460	5578	2714	5936	12699	32546	40194
	Young's Creek	69	54	152	271	104	34	11	6	12	26	66	82
	Buried sediment	27	21	58	104	40	13	4	2	5	10	25	31
	Outgoing sediment	34045	26432	74359	132798	50986	16481	5585	2717	5943	12715	32587	40244
Remaining distance to Bend Bay	Upstream sediment	34045	26432	74359	132798	50986	16481	5585	2717	5943	12715	32587	40244
	Buried sediment	32	25	70	126	48	16	5	3	6	12	31	38
	Outgoing sediment	34012	26407	74289	132672	50938	16465	5580	2715	5937	12703	32557	40206
Bend Bay	Upstream sediment	34012	26407	74289	132672	50938	16465	5580	2715	5937	12703	32557	40206
	Buried sediment	724	566	1669	3023	1173	397	164	85	101	259	695	860
	Outgoing sediment	33288	25841	72620	129650	49765	16068	5415	2630	5836	12444	31862	39346
Bend Bay to West Moira Lake	Upstream sediment	33288	25841	72620	129650	49765	16068	5415	2630	5836	12444	31862	39346
	Buried sediment	14	11	31	55	21	7	2	1	2	5	14	17
	Outgoing sediment	33274	25830	72589	129594	49744	16062	5413	2629	5834	12438	31848	39329

Model Segment	Parameter	Month (kg/month)											
		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
West Moira Lake	Upstream sediment	33274	25830	72589	129594	49744	16062	5413	2629	5834	12438	31848	39329
	Madoc Creek sediment	4268	3313	9310	16622	6380	2060	694	337	748	1595	4085	5044
	Buried sediment	4721	3695	11083	20175	7854	2699	1181	620	597	1661	4528	5617
	Outgoing sediment	32821	25448	70816	126041	48270	15422	4926	2346	5985	12373	31405	38756
East Moira Lake (EML)	Upstream sediment	32821	25448	70816	126041	48270	15422	4926	2346	5985	12373	31405	38756
	Buried sediment	10768	8404	24644	44569	17269	5816	2360	1213	1549	3873	10321	12782
	Outgoing sediment	22053	17044	46173	81472	31000	9606	2566	1133	4437	8500	21083	25974
EML to Stoco Lake	Upstream sediment	22053	17044	46173	81472	31000	9606	2566	1133	4437	8500	21083	25974
	Black River sediment	37880	27944	79864	146463	62735	23341	11830	10974	11563	16069	35342	46703
	Skootamatta R. sediment	69300	58058	139232	263762	114505	36135	13950	9276	13230	28350	60752	82833
	Buried sediment	791	1085	955	4372	3956	1589	1370	1412	353	618	-2	1235
	Outgoing sediment	128442	101961	264313	487326	204285	67494	26976	19970	28878	52300	117179	154274
Stoco Lake	Upstream sediment	128442	101961	264313	487326	204285	67494	26976	19970	28878	52300	117179	154274
	Clare River sediment	98568	89187	204317	351150	153033	26817	4472	3359	1664	3695	14190	25843
	Buried sediment	27995	25416	59820	104062	45552	8735	2366	1668	-16	873	4085	7556
	Outgoing sediment	199014	165733	408809	734414	311766	85576	29082	21661	30558	55123	127285	172560

A = active sediment area (m^2)

ϕ = sediment porosity (unitless)

ρ = sediment density (kg/L)

V_s = settling velocity (mm/yr)

[TSS] = TSS concentration (mg/L)

C = unit conversion factor

V_b = burial velocity (mm/yr)

All of these parameters, except for resuspension and settling velocity, have been defined by the sediment balance described above (Table 4.4-5). Settling velocities (V_s) were initially derived from sedimentation rates and TSS concentrations reported by Diamond (1995) using the following relationship:

$$\text{settling velocity (m/yr)} = \text{sedimentation rate (g/m}^2\text{/yr)} / \text{TSS concentration (g/m}^3\text{)} \qquad (10)$$

The resulting values were then scaled to reflect the changes in burial velocity required to achieve a sediment balance (i.e., final settling velocity = initial settling velocity * final burial velocity / initial burial velocity) (Table 4.4-7). The new settling rates were plugged back into Equation (9) to produce the corresponding resuspension velocities listed in Table 4.4-7.

Table 4.4-7
Settling and Resuspension Rates in the Moira River System

Model Segment	Settling Velocity		Resuspension Velocity (mm/yr)
	Initial (mm/yr)	Final (mm/yr)	
Deloro to Young's Creek	28077[a]	24335	1.79
Young's Creek to half way to Bend Bay	28077[a]	24647	1.81
Remaining distance to Bend Bay	28077[a]	25920	1.90
Bend Bay	140385[a]	156376	11.2
Bend Bay to West Moira Lake	28077[a]	24060	1.72
West Moira Lake	280769[b]	244407	15.2
East Moira Lake (EML)	121667[b]	55776	0.92
EML to Stoco Lake	60834[a]	62432	2.40
Stoco Lake	121667[a]	121474	4.59

[a] Assumed value based on settling velocities in East and West Moira Lake.
[b] Based on information from Diamond (1995).

4.4.4 Selected Metals of Concern

Model Equations

As stated in Section 4.4.1, the change in mass of arsenic, cobalt or nickel in the water compartment of a given model segment was calculated based on the following relationship:

$$\Delta m_{water} = \text{mass in} - \text{mass out} - \text{mass settled} + \text{mass resuspended} + \text{mass diffused}$$

or,

$$\Delta m_{water} = Q_{in}*[metal]_{in} - Q_{out}*[metal] - V_s*A*F_{pw}*[metal]*C + V_r*A*[metal]_{sed}*C + V_D*A*(F_{ds}*[metal]_{sed} - F_{dw}*[metal])*C \tag{11}$$

where: Q_{in} = inflow to model segment "x" (m^3/s)

$[metal]_{in}$ = total concentration of metal "z" in inflow to model segment "x" (µg/L)

Q_{out} = outflow from model segment "x" (m^3/s)

$[metal]$ = total concentration of metal "z" in model segment "x" (µg/L)

V_s = settling velocity (mm/yr)

A = active sediment area (m^2)

F_{pw} = fraction of metal "z" associated with suspended sediment (unitless)

V_r = resuspension velocity (mm/yr)

$[metal]_{sed}$ = total concentration of metal "z" in model segment "x" sediment (µg/L)

C = unit conversion factor

V_D = diffusion velocity (mm/yr)

F_{ds} = fraction of metal "z" dissolved in porewater (unitless)

F_{dw} = fraction of metal "z" dissolved in water (unitless)

Changes in the mass of arsenic, cobalt or nickel contained in surface sediments were calculated using a similar relationship:

$$\Delta m_{sed} = \text{mass settled} - \text{mass resuspended} - \text{mass diffused} - \text{mass buried}$$

or,

$$\Delta m_{sed} = V_s*A*F_{pw}*[metal] - V_r*A*[metal]_{sed} - V_D*A*(F_{ds}*[metal]_{sed} - F_{dw}*[metal])*C - V_b*A*[metal]_{sed} \qquad (12)$$

where: V_b = burial velocity (mm/yr)

Flow rates (Q), burial velocities (V_b), settling velocities (V_s), resuspension velocities (V_s) and active sediment areas (A) for each model segment have been defined through the water and sediment balances discussed in Sections 4.4.2 and 4.4.3, respectively. The remaining parameters were defined as follows:

Diffusion velocities (V_D) for arsenic, cobalt and nickel were derived using the following formula (Chapra 1997):

$$V_D = 69.35 * \phi * MW_{ion}^{-2/3} \qquad (13)$$

where: ϕ = sediment porosity (unitless)
MW_{ion} = molecular weight of the dominant ion (g/mol)

The dominant ionic form for arsenic, cobalt and nickel were assumed to be H_2AsO_4 (Cornett *et al.* 1987), Co and Ni (Cornett *et al.* 1987), respectively.

The **fraction of chemical dissolved in water (F_{dw})** was defined as:

$$F_{dw} = 1/(1 + K_w * [TSS]) \qquad (14)$$

where: K_w = partition coefficient for water (L/mg)
[TSS] = concentration of total suspended solids (mg/L)

The **fraction of chemical associated with suspended sediment (F_{pw})** was defined as:

$$F_{pw} = 1 - F_{dw} \qquad (15)$$

The **fraction of chemical dissolved in sediment porewater (F_{ds})** was defined as:

$$F_{ds} = 1/(1 + K_s * (1-\phi) * \rho) \qquad (16)$$

where: K_s = partition coefficient for sediment (L/g)
ϕ = sediment porosity (unitless)
ρ = sediment density (kg/L)

Tributary and Upstream Input

Young's Creek, Madoc Creek, the Black, Skootamatta and Clare rivers and the Moira River upstream of the Deloro Mine Site were assigned arsenic, cobalt and nickel concentrations based on average concentrations observed in each waterbody over the past 10 years (i.e., January 1990 to January 2000) (Table 4.4-8).

Table 4.4-8
Average Arsenic, Cobalt and Nickel Concentrations in Tributaries to the Moira River and in the Moira River Upstream of the Deloro Mine Site (1990 to 2000)

Waterbody	Sample Site[a]	Arsenic (µg/L)	Cobalt (µg/L)	Nickel (µg/L)
Moira River - upstream of Deloro	W1	1.0	0.7	2.3
Young's Creek	DM1	163.9	95.0	32.8
Madoc Creek	W4 and W5	1.1	0.3	1.3
Black River	W9	0.5	0.3	0.8
Skootamatta River	W10	0.5	0.3	0.8
Clare River	W12 and W13	0.8	0.3	2.0

[a] Sample locations are shown on Figure 2.1-1.

Loading from the Deloro Mine Site

The amount of arsenic, cobalt and nickel reaching the Moira River at or near the Deloro Mine Site was determined by examining water quality results from the following monitoring stations:

- W1 – at Malone upstream of Deloro;
- W2 – at Highway 7 bridge downstream of Deloro;
- DM7 – at Highway 7 bridge downstream of Deloro;

- DM1 – on Young's Creek near confluence with Moira River; and,
- DM8 – on Moira River immediately below confluence with Young's Creek.

Loading rates were calculated using mean annual concentrations for the past 10 years and average annual flow in Moira River recorded at Highway 7, as shown in Table 4.4-9.

Table 4.4-9
Loading Rates from the Deloro Mine Site to the Moira River

Parameter		Units	Arsenic	Cobalt	Nickel
Between Deloro and Highway 7 – Deloro Mine Site					
Water flow[a]	Upstream of Deloro	m³/s	4.18		
	Upstream of Young's Creek	m³/s	4.18		
Concentration	Upstream of Deloro	µg/L	1.0	0.7	2.3
	Upstream of Young's Creek	µg/L	43.3	4.5	5.6
Loading rates	Upstream of Deloro	kg/yr	132	93	304
	Upstream of Young's Creek	kg/yr	5713	594	739
	Deloro Mine Site	**kg/yr**	**5581**	**501**	**435**
Between Highway 7 and Downstream of Young's Creek – immediately below Deloro Mine Site					
Water flow[a]	Upstream of confluence with Young's Creek	m³/s	4.18		
	Young's Creek	m³/s	0.01		
	Downstream of confluence with Young's Creek	m³/s	4.19		
Concentration	Upstream of Young's Creek	µg/L	43.3	4.5	5.6
	Young's Creek	µg/L	163.9	95.0	32.8
	Downstream of confluence with Young's Creek	µg/L	52.1	29.6	8.7
Loading rates	Upstream of Young's Creek	kg/yr	5713	594	739
	Young's Creek	kg/yr	41	24	8
	Downstream of Young's Creek	kg/yr	6875	3906	1148
	Immediately below Deloro Mine Site	**kg/yr**	**1121**	**3288**	**401**

[a] Assuming that a negligible amount of water comes off the Deloro Mine Site.

Total estimated loading rates for the following contributing areas are summarized in Table 4.4-10:

- upstream of the Deloro Mine Site
- from Deloro Mine Site to Highway 7;

- Young's Creek; and,
- from Highway 7 to below confluence with Young's Creek.

Estimated loading rates are similar to those calculated by CG&S (1999). As noted by CG&S (1999), there is a significant amount of arsenic, cobalt and nickel entering the Moira River between Highway 7 and the confluence of Young's Creek.

Table 4.4-10
Summary of Estimated Loading Rates (kg/yr) to the Moira River near the Deloro Mine Site

Source	Arsenic	Cobalt	Nickel
Existing upstream load	132	93	304
Between Deloro Mine Site and Highway 7	5581	501	435
Young's Creek	41	24	8
Between Highway 7 and Young's Creek	1121	3288	401
Total	**6875**	**3906**	**1148**

Calibration Procedure

Based on information from Diamond (1990, 1995) and Cornett and Chant (1986), partition coefficients (K_w) for arsenic, cobalt and nickel in water were developed using the following equation:

$$K_w = (1 - [\text{d. metal}] / [\text{t. metal}]_w) / ([\text{d. metal}] / [\text{t. metal}]_w * [\text{TSS}]) \qquad (17)$$

where: [d. metal] = concentration of metal "z" dissolved in water (μg/L)
$[\text{t. metal}]_w$ = total concentration of metal "z" in water (μg/L)
[TSS] = concentration of total suspended solids (mg/L)

Sediment partition coefficients (K_s) were developed using information from Diamond (1990) and Azcue and Dixon (1994) in the equation:

$$K_s = (1 - [\text{p. metal}] / [\text{t. metal}]_s) / ([\text{p. metal}] / [\text{t. metal}]_s * (1-\phi) * \rho) \qquad (18)$$

where: [p. metal] = concentration of metal "z" in porewater (μg/L)
$[\text{t. metal}]_s$ = total concentration of metal "z" in surface sediments (μg/g)
ϕ = sediment porosity (unitless)
ρ = sediment density (kg/L)

Partition coefficients, diffusion velocities and initial water and sediment concentrations were then adjusted to calibrate the MRM, so that arsenic, cobalt and nickel concentrations predicted by the MRM matched trends observed in the river over the last 10 years. The calibration was performed under steady state conditions. It was deemed complete when the modelled concentrations in water reasonably reflected historical levels, and sediment concentrations were constant over time. Final parameter values used to calibrate the MRM are summarized in Tables 4.4-11 and 4.4-12, and results of the calibration are shown in Figures VI-1 to VI-24 (Appendix VI).

For arsenic and nickel, a good calibration was generally obtained in all model segments (Appendix VI, Figures VI-1 to VI-8 and VI-17 to VI-24). With cobalt, a good calibration was achieved in the five model segments upstream of West Moira Lake. The MRM consistently over-estimated cobalt concentrations during the open water season in the remaining four model segments, suggesting that there may be an additional sink for cobalt that is not included in the MRM (e.g., uptake by growing vegetation).

Table 4.4-11
Partition Coefficients and Diffusion Velocities Used to Calibrate the Moira River Model

Chemical	Partition Coefficient: Water (L/mg)	Partition Coefficient: Porewater (L/g)	Diffusion Velocity (mm/yr)
Arsenic	0.016	2.7	2.7
Cobalt	0.139[a] 0.070[b]	24.3	4.5
Nickel	0.099	0.18	4.5

[a] From Upstream of Deloro to the inlet of West Moira Lake.
[b] From West Moira Lake to the outlet of Stoco Lake.

Table 4.4-12
Initial Arsenic, Cobalt and Nickel Concentrations Used to Calibrate the Moira River Model

Model Segment	Arsenic		Cobalt		Nickel	
	Water (µg/L)	Sediment (µg/g)	Water (µg/L)	Sediment (µg/g)	Water (µg/L)	Sediment (µg/g)
Deloro to Young's Creek	43.3	315	4.5	214	5.6	130
Young's Creek to half way to Bend Bay	52.1	380	10.3	490	8.7	210
Remaining distance to Bend Bay	52.1	390	10.3	505	8.7	220
Bend Bay	52.1	705	10.3	895	8.7	500
Bend Bay to West Moira Lake	52.1	370	10.3	490	8.7	200
West Moira Lake	53.0	650	9.8	490	8.1	490
East Moira Lake (EML)	76.0	375	13.3	300	10.5	225
EML to Stoco Lake	19.0	88	3.3	69	3.2	80
Stoco Lake	18.0	93	3.1	67	3.2	105

4.5 Model Implementation

Once calibrated, the MRM was used to: (1) predict arsenic, cobalt and nickel concentrations downstream of the Deloro Mine Site assuming that all loading from the Deloro Mine Site ceased; and, (2) determine the level of cleanup required on site for downstream arsenic, cobalt and nickel concentrations in water to reach, or fall below, PWQOs and provincial sediment quality guidelines (PSQGs) for the protection of aquatic life.

4.5.1 No Loading Scenarios

As a result of short retention times (Table 4.4-3), arsenic concentrations in the water column quickly dropped below the interim PWQO of 5 µg/L (MOE 1999) after all arsenic loading from the Deloro Mine Site, between Highway 7 and Young's Creek, and Young's Creek was eliminated (Table 4.4-13). The interim PWQO for arsenic of 5 µg/L was used for this component, because the MOE has stated that one of the objectives of the final cleanup plan for the Deloro Mine Site is to meet this interim PWQO. Arsenic concentrations in surface sediments remained above the Ontario sediment Severe Effect Level (SEL) guideline of 33 µg/g (MOE 1993) at all model segments for the first 10 years, then declined to less than the SEL in some portions of Moira Lake and Stoco Lake after 20 years.

Table 4.4-13
Predicted Concentrations of Arsenic Downstream Assuming No Arsenic Loading from Deloro Mine Site

Model Segment	Initial	After				Provincial Guideline[a]
		5 yrs	10 yrs	20 yrs	30 yrs	
Water (µg/L)[b,c]						
Deloro to Young's Creek	**43.3**	1.0 - 1.1	1.0 - 1.1	1.0 - 1.0	1.0 - 1.0	5.0
Young's Creek to half way to Bend Bay	**52.1**	1.0 - 1.2	1.0 - 1.2	1.0 - 1.1	1.0 - 1.1	
Remaining distance to Bend Bay	**52.1**	1.0 - 1.4	1.0 - 1.3	1.0 - 1.2	1.0 - 1.1	
Bend Bay	**52.1**	1.2 - 2.2	1.1 - 1.7	1.0 - 1.3	1.0 - 1.2	
Bend Bay to West Moira Lake	**52.1**	1.3 - 2.3	1.1 - 1.7	1.0 - 1.3	1.0 - 1.2	
West Moira Lake	**53.0**	2.0 - 2.8	1.4 - 1.8	1.1 - 1.2	1.0 - 1.1	
East Moira Lake (EML)	**76.0**	2.4 - 3.4	1.7 - 2.4	1.2 - 1.7	1.1 - 1.4	
EML to Stoco Lake	**19.0**	0.8 - 1.2	0.7 - 1.0	0.6 - 0.8	0.6 - 0.7	
Stoco Lake	**18.0**	0.9 - 1.2	0.8 - 1.0	0.7 - 0.8	0.7 - 0.7	
Sediment (µg/g)[c,d]						
Deloro to Young's Creek	**315**	**243**	**196**	**129**	**88**	6.0 (LEL)
Young's Creek to half way to Bend Bay	**380**	**293**	**236**	**154**	**105**	33 (SEL)
Remaining distance to Bend Bay	**390**	**299**	**239**	**154**	**105**	
Bend Bay	**705**	**299**	**149**	**44**	21	
Bend Bay to West Moira Lake	**370**	**287**	**233**	**153**	**106**	
West Moira Lake	**650**	**226**	**98**	27	16	
East Moira Lake (EML)	**375**	**290**	**230**	**144**	**96**	
EML to Stoco Lake	**88**	**64**	**48**	28	18	
Stoco Lake	**93**	**58**	**38**	19	12	

[a] Water quality objective from MOE (1999); sediment quality guidelines from MOE (1993).
[b] Concentrations in water reported as minimum to maximum levels observed in Year 5, 10, 20 or 30.
[c] Values in **bold** exceed the PWQO or the Severe Effect Level (SEL) sediment guideline.
[d] Sediment concentrations at the end of Year 5, 10, 20 or 30.

Cobalt concentrations in the water column decreased rapidly after loading from the Deloro Mine Site, Young's Creek and between Highway 7 and Young's Creek ceased (Table 4.4-14). However, up to 30 years after all loading to the river ceased, cobalt levels in Bend Bay and Moira Lake remained above the PWQO of 0.9 µg/L for at least part of the year. Cobalt concentrations in surface sediments were below screening level concentrations (SLC) in Moira and Stoco lakes 10 years after all cobalt loading to the Moira River ceased (Table 4.4-14). Sediment cobalt concentrations in all model segments were less than the SLC of 296 µg/g after 20 years.

Initial nickel concentrations in water in all model segments were below the PWQO of 25 µg/L (MOE 1999). They decreased to background levels after all nickel discharges from the Deloro Mine Site and adjacent areas, including Young's Creek stopped (Table 4.4-15). Surficial sediments initially contained nickel concentrations in excess of the provincial SEL guideline of 75 µg/g (MOE 1993). Nickel levels in the surface sediment exceeded the SEL in all model segments, except East Moira Lake to Stoco Lake, 10 years after nickel loading ceased. Nickel levels declined below the SEL in the Deloro to Young's Creek and Stoco Lake model segments after 20 years. They remained above the SEL in Bend Bay and Moira Lake even after 30 years.

Table 4.4-14
Predicted Concentrations of Cobalt Downstream Assuming No Cobalt Loading from Deloro Mine Site

Model Segment	Initial	After				Provincial Guideline[a]
		5 yrs	10 yrs	20 yrs	30 yrs	
Water (µg/L)[bc]						
Deloro to Young's Creek	**4.5**	0.7 – 0.7	0.7 - 0.7	0.7 - 0.7	0.7 - 0.7	0.9
Young's Creek to half way to Bend Bay	**10.3**	0.7 – 0.9	0.7 - 0.9	0.7 - 0.8	0.7 - 0.8	
Remaining distance to Bend Bay	**10.3**	0.7 – **1.1**	0.7 - **1.0**	0.7 - 0.9	0.7 - 0.9	
Bend Bay	**10.3**	**1.0 – 2.1**	0.8 - **1.5**	0.7 - **1.1**	0.7 - **1.0**	
Bend Bay to West Moira Lake	**10.3**	**1.0 – 2.1**	0.9 - **1.6**	0.7 - **1.1**	0.7 - **1.0**	
West Moira Lake	**9.8**	**1.4 – 2.1**	**1.0 - 1.4**	0.7 - 0.9	0.6 - 0.8	
East Moira Lake (EML)	**13.3**	**1.6 – 2.4**	**1.2 - 1.8**	0.8 - **1.2**	0.7 - **1.0**	
EML to Stoco Lake	**3.3**	0.2 – 0.6	0.2 - 0.5	0.1 - 0.3	0.1 - 0.3	
Stoco Lake	**3.1**	0.3 – 0.6	0.2 - 0.4	0.1 - 0.3	0.1 - 0.2	
Sediment (µg/g)[cd]						
Deloro to Young's Creek	214	174	147	107	83	296 (SLC)
Young's Creek to half way to Bend Bay	**490**	**388**	**321**	222	162	
Remaining distance to Bend Bay	**505**	**398**	**328**	225	163	
Bend Bay	**895**	**425**	243	104	70	
Bend Bay to West Moira Lake	**490**	**394**	**329**	230	169	
West Moira Lake	**490**	220	121	53	38	
East Moira Lake (EML)	**300**	247	205	141	102	
EML to Stoco Lake	69	54	42	27	18	
Stoco Lake	67	45	32	17	11	

[a] Water quality objective from MOE (1999); Screening Level Concentration (SLC) calculated according to MOE (1993).
[b] Concentrations in water reported as minimum to maximum levels observed in Year 5, 10, 20 or 30.
[c] Values in **bold** exceed the PWQO or the SLC.
[d] Sediment concentrations at the end of Year 5, 10, 20 or 30.

Table 4.4-15
Predicted Concentrations of Nickel Downstream Assuming No Nickel Loading from Deloro Mine Site

Model Segment	Initial	After				Provincial Guideline[a]
		5 yrs	10 yrs	20 yrs	30 yrs	
Water (μg/L)[b]						
Deloro to Young's Creek	5.6	2.3 - 2.4	2.3 - 2.3	2.3 - 2.3	2.3 - 2.3	25
Young's Creek to half way to Bend Bay	8.7	2.3 - 2.5	2.3 - 2.4	2.3 - 2.4	2.3 - 2.4	
Remaining distance to Bend Bay	8.7	2.3 - 2.6	2.3 - 2.6	2.3 - 2.5	2.3 - 2.4	
Bend Bay	8.7	2.4 - 3.6	2.3 - 3.2	2.3 - 2.9	2.3 - 2.8	
Bend Bay to West Moira Lake	8.7	2.4 - 3.6	2.3 - 3.2	2.3 - 2.9	2.3 - 2.8	
West Moira Lake	8.1	2.6 - 3.9	2.3 - 3.2	2.1 - 2.8	2.1 - 2.7	
East Moira Lake (EML)	10.5	2.6 - 3.8	2.2 - 3.2	2.0 - 2.7	1.9 - 2.5	
EML to Stoco Lake	3.2	1.0 - 1.6	1.0 - 1.4	1.0 - 1.3	0.9 - 1.2	
Stoco Lake	3.2	1.5 - 1.6	1.4 - 1.5	1.3 - 1.5	1.3 - 1.4	
Sediment (μg/g)[cd]						
Deloro to Young's Creek	**130**	**105**	**90**	72	63	16 (LEL)
Young's Creek to half way to Bend Bay	**210**	**159**	**130**	**93**	75	75 (SEL)
Remaining distance to Bend Bay	**220**	**166**	**135**	**96**	77	
Bend Bay	**500**	**268**	**188**	**137**	**126**	
Bend Bay to West Moira Lake	**200**	**154**	**126**	**91**	73	
West Moira Lake	**490**	**266**	**190**	**140**	**130**	
East Moira Lake (EML)	**225**	**183**	**153**	**111**	**89**	
EML to Stoco Lake	**80**	68	60	49	45	
Stoco Lake	**105**	**91**	**82**	73	69	

[a] Water quality objective from MOE (1999); sediment quality guidelines from MOE (1993).
[b] Concentrations in water reported as minimum to maximum levels observed in Year 5, 10, 20 or 30.
[c] Values in **bold** exceed the PWQO or the Severe Effect Level (SEL) sediment guidelines.
[d] Sediment concentrations at the end of Year 5, 10, 20 or 30.

4.5.2 Level of Cleanup of the Deloro Mine Site Required to Meet Cleanup Objectives

Should arsenic migration from the Deloro Mine Site be essentially eliminated (e.g., 99% reduction) the model results indicate that arsenic concentrations in the Moira River at Highway 7 (which is located in the first model segment – Deloro to Young's Creek) would meet the interim PWQO during periods of high flow only (Table 4.4-16). During periods of low flow, arsenic levels would continue to exceed the interim PWQO 30 years after Deloro Mine Site cleanup. This is because a relatively small amount of arsenic from the Deloro Mine Site, coupled with relatively high background concentrations in the Moira River upstream of the mine, would still be significant relative to the interim PWQO of 5 µg/L. The interim PWQO for arsenic would be met year round in and downstream of Moira Lake within 5 years of 99% reduction in loading (Table 4.4-16). The continual release of arsenic from sediments in the bottom of Moira Lake is expected to have slight effect on arsenic concentrations in lake water, but not to the extent that the interim PWQO would be exceeded.

Table 4.4-16
Predicted Arsenic Levels Downstream Assuming a 99% Reduction in the Amount of Arsenic Released from the Deloro Mine Site

Model Segment	Initial	After				Provincial Guideline[a]
		5 yrs	10 yrs	20 yrs	30 yrs	
Water (µg/L)[b,c]						
Deloro to Young's Creek	**43.3**	1.1 - **7.3**	1.1 - **7.3**	1.1 - **7.2**	1.1 - **7.2**	5.0
Young's Creek to half way to Bend Bay	**52.1**	1.2 - **8.5**	1.2 - **8.4**	1.2 - **8.4**	1.2 - **8.4**	
Remaining distance to Bend Bay	**52.1**	1.2 - **8.1**	1.2 - **8.0**	1.2 - **7.9**	1.2 - **7.9**	
Bend Bay	**52.1**	1.4 - **8.2**	1.3 - **7.6**	1.2 - **7.2**	1.2 - **7.1**	
Bend Bay to West Moira Lake	**52.1**	1.4 - **7.8**	1.3 - **7.3**	1.2 - **6.8**	1.2 - **6.7**	
West Moira Lake	**53.0**	2.2 - 4.7	1.6 - 3.7	1.2 - 3.1	1.2 - 3.0	
East Moira Lake (EML)	**76.0**	2.6 - 4.0	1.9 - 3.1	1.5 - 2.4	1.3 - 2.2	
EML to Stoco Lake	**19.0**	0.8 - 1.5	0.7 - 1.2	0.6 - 1.0	0.6 - 1.0	
Stoco Lake	**18.0**	1.0 - 1.4	0.8 - 1.2	0.8 - 1.0	0.7 - 0.9	
Sediment (µg/g)[c,d]						
Deloro to Young's Creek	**315**	**244**	**197**	**130**	**91**	6.0 (LEL)
Young's Creek to half way to Bend Bay	**380**	**294**	**237**	**156**	**108**	33 (SEL)
Remaining distance to Bend Bay	**390**	**300**	**241**	**157**	**108**	
Bend Bay	**705**	**303**	**155**	**50**	**28**	
Bend Bay to West Moira Lake	**370**	**288**	**234**	**155**	**108**	
West Moira Lake	**650**	**231**	**104**	33	22	
East Moira Lake (EML)	**375**	**290**	**231**	**147**	**99**	
EML to Stoco Lake	**88**	**64**	**48**	29	19	
Stoco Lake	**93**	**58**	**39**	20	13	

[a] Water quality objective from MOE (1999); sediment quality guidelines from MOE (1993).
[b] Concentrations in water reported as minimum to maximum levels observed in Year 5, 10, 20 or 30.
[c] Values in **bold** exceed the PWQO or the SEL.
[d] Sediment concentrations at the end of Year 5, 10, 20 or 30.

Arsenic concentrations in surface sediments are projected to remain above the SEL for 10 years in all model segments after a 99% reduction in the amount released from the Deloro Mine Site and surrounding area (Table 4.4-16). After 30 years, arsenic would continue to exceed the SEL in all model segments, except in West Moira Lake, East Moira Lake to Stoco Lake and Stoco Lake.

The nickel PWQO of 25 µg/L is currently being met in all model segments on an annual average basis. However, exceedances occur in the section between the mine site and Bend Bay during periods of low flow (Appendix I). The PWQO would be met year-round after a 75% reduction in nickel loading (Table 4.4-17).

Nickel concentrations in surface sediments are projected to remain above the SEL in all model segments, except between East Moira Lake and Stoco Lake, 30 years after a 75% reduction in total nickel loading to Moira River (Table 4.4-17).

Model results indicate that cobalt concentrations will continue to exceed the PWQO of 0.9 µg/L as far downstream as the outlet of Moira Lake, even with the elimination of 95% of cobalt loadings from the Deloro Mine Site and adjacent area (Table 4.4-18). Below Moira Lake, cobalt concentrations would meet the PWQO within 5 years, because of the effects of dilution from the Black and Skootamatta rivers.

Following a 95% reduction in total cobalt loading from the Deloro Mine Site and surrounding area, cobalt levels in surface sediments in the Moira River between Young's Creek and Moira Lake would fall below the SLC of 296 µg/g within 20 years (Table 4.4-18). In the other model segments, sediment cobalt levels are either currently below the SLC or projected to drop below the SLC within 5 years.

Table 4.4-17
Predicted Nickel Levels Downstream Assuming a 75% Reduction in the Amount of Nickel Released from the Deloro Mine Site

Model Segment	Initial	After				Provincial Guideline[a]
		5 yrs	10 yrs	20 yrs	30 yrs	
Water (µ g/L)[bc]						
Deloro to Young's Creek	5.6	2.5 – 14	2.5 – 14	2.5 – 14	2.5 – 14	25
Young's Creek to half way to Bend Bay	8.7	2.8 – 25	2.8 – 25	2.8 – 25	2.8 – 25	
Remaining distance to Bend Bay	8.7	2.8 – 24	2.8 – 24	2.8 – 24	2.8 – 24	
Bend Bay	8.7	2.9 – 22	2.8 – 21	2.8 – 21	2.8 – 21	
Bend Bay to West Moira Lake	8.7	2.9 – 21	2.8 – 20	2.8 – 20	2.8 – 20	
West Moira Lake	8.1	3.1 – 9.4	2.8 – 8.9	2.7 – 8.5	2.7 – 8.5	
East Moira Lake (EML)	10.5	3.1 – 5.8	2.9 – 5.4	2.7 – 5.0	2.6 – 4.9	
EML to Stoco Lake	3.2	1.1 – 2.1	1.1 – 2.0	1.1 – 1.9	1.0 – 1.9	
Stoco Lake	3.2	1.5 – 2.1	1.5 – 2.0	1.5 – 1.9	1.5 – 1.9	
Sediment (µ g/g)[de]						
Deloro to Young's Creek	**130**	**111**	**100**	**87**	**80**	16 (LEL)
Young's Creek to half way to Bend Bay	**210**	**172**	**150**	**122**	**109**	75 (SEL)
Remaining distance to Bend Bay	**220**	**179**	**156**	**126**	**112**	
Bend Bay	**500**	**326**	**266**	**228**	**220**	
Bend Bay to West Moira Lake	**200**	**166**	**145**	**119**	**106**	
West Moira Lake	**490**	**322**	**264**	**227**	**220**	
East Moira Lake (EML)	**225**	**194**	**172**	**141**	**125**	
EML to Stoco Lake	**80**	71	65	57	53	
Stoco Lake	**105**	**95**	**88**	**81**	**79**	

[a] Water quality objective from MOE (1999); sediment quality guidelines from MOE (1993).
[b] Concentrations in water reported as minimum to maximum levels observed in Year 5, 10, 20 or 30.
[c] "Initial" nickel concentrations = nickel concentrations at the end of December; during summer low flows, nickel concentrations can increase beyond initial segment concentrations.
[d] Sediment concentrations at the end of Year 5, 10, 20 or 30.
[e] Values in **bold** exceed the PWQO or the SEL.

Table 4.4-18
Predicted Cobalt Levels Downstream of the Deloro Mine Site Assuming a 95% Reduction in the Amount of Cobalt Released from the Mine Site

Model Segment	**Initial**	**After**				**Provincial Guidelines**[a]
		5 yrs	**10 yrs**	**20 yrs**	**30 yrs**	
Water (µg/L)[bc]						
Deloro to Young's Creek	**4.5**	0.8 - **3.5**	0.8 - **3.5**	0.8 - **3.5**	0.8 - **3.5**	0.9
Young's Creek to half way to Bend Bay	**10.3**	0.9 - **7.7**	0.9 - **7.7**	0.9 - **7.6**	0.9 - **7.6**	
Remaining distance to Bend Bay	**10.3**	0.9 - **7.5**	0.9 - **7.4**	0.9 - **7.3**	0.9 - **7.3**	
Bend Bay	**10.3**	**1.1 - 7.4**	**1.0 - 6.9**	0.9 - **6.5**	0.9 - **6.4**	
Bend Bay to West Moira Lake	**10.3**	**1.1 - 7.1**	**1.0 - 6.6**	0.9 - **6.2**	0.9 - **6.0**	
West Moira Lake	**9.8**	**1.6 - 3.8**	**1.2 - 3.1**	0.9 - **2.6**	0.8 - **2.5**	
East Moira Lake (EML)	**13.3**	**1.8 - 2.9**	**1.3 - 2.3**	**1.0 - 1.8**	0.9 - **1.6**	
EML to Stoco Lake	**3.3**	0.2 - 0.8	0.2 - 0.6	0.1 - 0.5	0.1 - 0.5	
Stoco Lake	**3.1**	0.3 - 0.7	0.2 - 0.6	0.2 - 0.4	0.2 - 0.4	
Sediment (µg/g)[cd]						
Deloro to Young's Creek	214	176	150	113	90	296 (SLC)
Young's Creek to half way to Bend Bay	**490**	**393**	**329**	235	179	
Remaining distance to Bend Bay	**505**	**403**	**337**	239	181	
Bend Bay	**895**	**449**	275	144	112	
Bend Bay to West Moira Lake	**490**	**399**	**337**	243	185	
West Moira Lake	**490**	233	140	75	60	
East Moira Lake (EML)	**300**	249	210	149	112	
EML to Stoco Lake	69	54	44	29	21	
Stoco Lake	67	46	34	19	13	

[a] Water quality objective from MOE (1999); Screening Level Concentration (SLC) calculated according to MOE (1993).

[b] Concentrations in water reported as minimum to maximum levels observed in Year 5, 10, 20 or 30.

[c] Values in **bold** exceed the PWQO or reference sediment concentrations

[d] Sediment concentrations at the end of Year 5, 10, 20 or 30.

4.6 Conclusions

Results from this modelling exercise indicate that:

- Total arsenic loading from the Deloro Mine Site and the surrounding area would have to be essentially eliminated (99% reduction) for arsenic concentrations in Moira Lake and downstream to be less than the interim PWQO of 5 µg/L during average summer low flows. Even with 99% reduction, arsenic will remain above the interim PWQO between the Deloro Mine Site and Moira Lake at low flows.

- Total nickel loading rates from the Deloro Mine Site and the surrounding area would have to be reduced by 75% for nickel concentrations at Highway 7 and downstream to be equivalent to, or less than, the PWQO of 25 µg/L year round.
- Cobalt concentrations are projected to exceed the PWQO downstream of the Deloro Mine Site to East Moira Lake for the 30-year period of the model, even with 95% cleanup of the Deloro Mine Site and the surrounding area. If total cobalt loading rates were reduced by 95%, cobalt concentrations downstream of East Moira Lake are projected to drop below the PWQO following the addition of dilution water through the Black & Skootamatta rivers.
- Arsenic and nickel concentrations in surface sediments immediately downstream of the Deloro Mine Site are projected to remain above guideline levels for some time (i.e., >30 years), regardless of the level of on-site cleanup.
- Following a 95% reduction in total cobalt loading from the Deloro Mine Site and surrounding area, cobalt levels in surface sediments in the Moira River between Young's Creek and Moira Lake would fall below the SLC of 296 µg/g within 20 years. In the other model segments, downstream of Moira Lake, sediment cobalt levels are either currently below the SLC or projected to drop below the SLC within 5 years.
- Since Young's Creek contributes relatively small amounts of arsenic, nickel and cobalt to the Moira River in comparison to discharge released directly from the Deloro Mine Site, the greatest benefit will be from cleanup efforts focussed on the Deloro Mine Site. However, there is a concern about the Deloro Mine Site derived sediments currently being held back behind a series of beaver dams on Young's Creek (see Chapters 2.2 and 5.0). Were these dams to completely fail, a significant quantity of sediment could be released to the Moira River (see Appendix VIII for a description of the results of a partial beaver dam failure in June 2000).

References

Azcue, J. M and D.G. Dixon. 1994. Effects of past mining activities on the arsenic concentration in fish from Moira Lake, Ontario. J. Great Lakes Res. 20(4):717-724.

Bosworth, W.S. and L. J. Thibodeaux. 1990. Bioturbation: a facilitator of contaminant transport in bed sediment. Environmental Progress, 9(4): 211-217.

CG&S (CH2M Gore & Storrie Ltd.). 1999. Deloro Mine rehabilitation project, development of a sitewide water and load balance - final report. Prepared for the Ontario Ministry of the Environment. May 1999.

Chapra, S.C. 1997. Surface water-quality modeling. McGraw-Hill International Editions, Civil Engineering Series, Toronto, Canada.

Cornett, R.J. and L. Chant. 1986. Speciation of arsenic and nickel in sediments of Moira Lake. Prepared for the National Uranium Tailings Program, Canadian Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada, Ottawa, Canada. DSS File No. O5Gs.23241-5-1716.

Cornett, R.J., B. Risto, and L. Chant. 1987. Kinetics of arsenic and nickel in sediments in Moira Lake. Prepared for the National Uranium Tailings Program, Canadian Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada, Ottawa, Canada. DSS Contract No. 23317-6-1736/OI-SQ.

Diamond, M. L. 1990. Modelling the fate and transport of arsenic and other inorganic chemicals in lakes. Ph.D. Thesis, University of Toronto, Toronto, Canada.

Diamond, M. L. 1995. Application of a mass balance model to assess in-place arsenic pollution. Environ. Sci. Technol. 29:29-42.

Environment Canada. 1994. Canadian monthly climate data and 1961-1990 normals, 1994 release. Environment Canada, Ottawa, Canada.

Environment Canada. 1999. HYDAT, Version 96 - 1.05.8: Surface water and sediment data to 1996. Atmospheric Environment Service, Environment Canada, Ottawa, Canada.

HPS (High Performance System Inc.). 1997. STELLA software and technical documentation.

MOE (Ontario Ministry of the Environment). 1972. Report on water quality in Stoco Lake. Ontario Ministry of the Environment, Toronto, Canada.

MOE. 1974. Water Resources of the Moira River drainage basin. Ontario Ministry of the Environment, Toronto, Canada. MOE Water Resources Report 6.

MOE. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment, Toronto, Canada. August 1993.

MOE. 1999. Water management policies, guidelines and provincial water quality objectives of the Ministry of Environment and Energy. Ontario Ministry of the Environment, Toronto, Canada. February 1999.

Mudroch, A. and J.A. Capobianco. 1980. Impact of past mining activities on aquatic sediments in Moira River Basin, Ontario. J. Great Lakes Res., 6(2):121-128.

WSC (Water Survey of Canada). 2000. Monthly water flow data from 1997 to 1999 for the Moira River.

5. CONCLUSIONS AND RECOMMENDATIONS

The answers to the main study questions are as follows:

1. Are metals entering the Moira River system?

Water

Yes, but water concentrations have declined. Recent mean annual arsenic and nickel concentrations do not exceed the PWQO at any of the stations downstream of the Deloro Mine Site, although some exceedances occur seasonally during low-flow. Recent mean annual cobalt, copper and lead concentrations do not exceed the PWQO downstream of Moira Lake. Radioactive substances (e.g., uranium or radium-226) are not elevated in water at any location in the Moira River system.

Sediments

Yes, a substantial increase in the concentration of metals in sediment occurs downstream of the Deloro Mine Site, followed by an additional increase downstream of the confluence with Young's Creek. The highest concentrations observed in this study occurred in the Young's Creek sediment sample for most metals of concern. The sediments in Young's Creek are currently being held back behind a series of beaver dams. Metal concentrations in sediment within the Moira River gradually decline after the confluence with Young's Creek, with the most substantial drop occurring after the Moira Lake outlet. Concentrations remain elevated above reference values all the way to the farthest downstream station (Corbyville), except for lead and uranium.

Provincial sediment quality guidelines (Severe Effect Levels) for arsenic and nickel are exceeded at the stations from Highway 7 through to Moira Lake, and also at some stations in Stoco Lake. Copper concentrations are above the SEL in Young's Creek, Bend Bay and Moira Lake. Lead concentrations vary throughout the Moira River system and the reference systems; therefore, lead concentrations appear to be related to local geology rather than to the Deloro Mine Site. Cobalt concentrations exceed site-specific Screening Level Concentrations (SLC) in Young's Creek and from Highway 7 through to the outlet of Moira Lake. Silver concentrations exceed the SLC from downstream of Young's Creek through to the mid-basin station of Moira Lake. Uranium concentrations are significantly above reference concentrations in Young's Creek only; however, the radioactivity from the amount of uranium present is indistinguishable from reference levels. Other radionuclides are not a concern at any location in the Moira River system.

Sentinel Fish Species

Yes, metal concentrations in whole body white sucker samples are significantly higher than reference locations in the Moira River system, particularly at Bend Bay and Moira Lake. There are no differences in metal concentrations between smaller white sucker (< 30 cm length) and larger white sucker (> 30 cm length).

Arsenic, silver and nickel are the only metals that have significantly higher concentrations in longnose dace at the site downstream of the Deloro Mine Site compared to the two upstream sites. Arsenic is the most elevated relative to the reference data.

Sport Fish Species

Based on the findings of MOE (1999), metals of concern in fillets of sport fish species from the Moira River system are at concentrations below those that could require restrictions of fish consumption. This is supported by CanTox (1999), who reported that levels of arsenic in fish considered in the Deloro Village risk assessment study were consistent with those observed elsewhere in Ontario.

2. Is there a measurable biological response in aquatic invertebrates and fish?

Overall, there are some changes in the benthic community structure of lakes in the Moira River system that are consistent with the effects of metal concentrations, but these changes are quite subtle. Total abundance is not affected by metal concentrations in the exposed lakes, and species richness is only reduced in Moira Lake (although the pattern of richness in Moira Lake did not correspond with metal concentrations). Lake sediments are not toxic to *Hyalella azteca* or *Chironomus riparius* in laboratory toxicity tests. However, the abundance and percentage of metal-sensitive invertebrates is significantly reduced in both exposed lakes and in Bend Bay relative to both reference lakes. In addition, the among-lake variation in abundance of a number of individual taxa is consistent with their relative metal-sensitivities.

The variation in total abundance within the Moira River appears to be related to habitat attributes rather than sediment metal concentrations. Total abundance varies moderately, but without a noticeable trend from upstream of the Deloro Mine Site to downstream. There is a significant positive relationship between sediment metal concentrations and species richness, which is contrary to expectations. This may be because the metals are largely in the more unavailable forms, such as the residual, oxides or organic/sulphide fractions. The toxicity test results did not show a consistent relationship between effects on growth or survival of *Hyalella azteca* or *Chironomus riparius* and metal concentrations.

There are effects on benthic invertebrate abundance and species richness in Young's Creek. The sediments are toxic to *Hyalella azteca* and *Chironomus riparius* in laboratory toxicity tests.

There are no obvious adverse effects on white sucker characteristics in Moira Lake. The only observed difference is that female white sucker are older in Moira Lake. All other characteristics in white sucker from Moira Lake are intermediate between Round Lake and Consecon Lake.

Despite the exposure (and uptake) of the metals of concern, whole-organism characteristics of longnose dace do not reflect the increase in metal concentrations. It is possible that concentrations are not high enough to cause individual or population level changes in resident fishes. Alternatively, longnose dace may not be sensitive to increased metal concentrations.

3. Are the metals in the system causing the biological response observed in invertebrates and fish?

The weight of evidence from the benthic invertebrate community data suggests a weak relationship between metals and the presence of some sensitive invertebrate species in lakes within the Moira River system. The weight of evidence from the sentinel fish species data suggests that there is no readily apparent cause-effect relationship between metal concentrations and the whole-organism and population responses measured.

4. Do the metal concentrations present in water and sediment of the Moira River system pose a risk to human health?

Cadmium, chromium, cobalt, lead, and nickel do not represent a potential health risk in any study area and further assessment of the potential health risks posed by these metals is not required.

Arsenic in Study Areas C and D is not expected to lead to significantly elevated exposures compared to the TOR, and further assessment of the potential health risks posed by this substance in these areas is not warranted.

The reminder issued by the MOE and the Hastings and Prince Edward Counties Health Unit to residents of Study Areas A and B (from the Deloro Mine Site to the outlet of Moira Lake) advising them not to drink the water was, and continues to be, appropriate. The reminder is not only appropriate because of concerns about arsenic, but also because of the risk of exposure to pathogens in untreated water. If residents drink untreated water from the river or lake, they would have greater estimated levels of exposure to arsenic than the TOR under the conservative conditions assumed in this assessment. Where water is not used for drinking, arsenic is not a concern for residents and cottagers on Moira Lake.

The section of the river above Moira Lake (Study Area A) is not well suited for in-water recreational activities and has only a limited number of residences. However, recreational use of this section of the river system may be an important exposure pathway, at least for some individuals. The amount of exposure through this pathway, both in absolute terms and relative to total arsenic exposure, requires further study. [This further study has since been conducted. The results show that exposure to the range of concentrations of arsenic detected in sediment in Study Area A will not result in adverse health effects after short-term or long-term exposure of area residents and other users of the river. Therefore, no specific risk management measures are required with respect to exposure to sediments in Study Area A.].

Metals of concern in fish fillets from the Moira River system are at concentrations below those that could require restrictions of fish consumption. However a fish consumption restriction for Moira and Stoco Lakes is in effect because of mercury; a substance not related to the Deloro Mine Site. Consumption restrictions based on mercury are widespread throughout Ontario's lakes and rivers, including the reference lakes considered for this *Study*.

5. What amount of clean up would be necessary at the Deloro site to meet Provincial Water Quality Objectives in the Moira River and to reduce sediment concentrations to below concentrations associated with biological effects?

The predictive model showed that total arsenic and cobalt loading from the Deloro Mine Site and surrounding area would have to be essentially eliminated for downstream water quality to meet PWQOs. For arsenic, the interim PWQO of 5 µg/L would not be met at Highway 7 during average summer low flows even with 99% reduction. However, arsenic concentrations would be less than 5 µg/L year-round in Moira Lake and farther downstream.

Cobalt concentrations are projected to exceed the PWQO downstream of the Deloro Mine Site to East Moira Lake for the 30-year period of the model, even with 95% reduction of loadings from the Deloro Mine site and surrounding area. If total cobalt loading rates from the Deloro Mine Site and surrounding area were reduced by 95%, cobalt concentrations downstream of East Moira Lake are projected to drop below the PWQO following the addition of dilution water by the Black and Skootamatta Rivers.

Total nickel loading rates to the Moira River would have to be reduced by 75% for downstream nickel concentrations to be equivalent to, or less than, the PWQO of 25 µg/L year round.

Arsenic and nickel concentrations in surface sediments immediately downstream of Deloro are projected to remain above guideline levels for the 30-year period of the model, regardless of the levels of clean up completed on site. Following a 95% reduction in total cobalt loading from the Deloro Mine Site and surrounding area, cobalt concentrations in surface sediments in the Moira River between Young's Creek and Moira Lake would fall below the SLC of 296 µg/g within 20 years. In the other model segments downstream of Moira Lake, sediment cobalt levels are either currently below the SLC or projected to drop below the SLC within 5 years.

The relative metal loading from Young's Creek is small compared to loading from the Deloro Mine Site. Therefore, the most benefit will be gained by focussing on the cleanup of the Deloro Mine Site. However, a significant quantity of sediment is present in Young's Creek, currently contained behind a series of beaver dams. The potential exists for a failure of these dams, as illustrated by a partial failure in June 2000. Therefore, a sudden release of sediments into the

Moira River is possible. The magnitude will depend upon the extent of the beaver dam failures and flow in Young's Creek.

It should be emphasized that meeting PWQOs and Severe Effect Level or Lowest Effect Level Guidelines for sediments after cleanup does not appear to be necessary to prevent effects on aquatic biota, because current conditions do not appear to be causing significant effects.

Overall Goal and Conclusions

The overall goal of the study was to assess the extent and significance of metals concentrations and predict the environmental response to cleanup activities that will in the future be conducted at the Deloro Mine Site. The three components of this study have shown the following:

1. The study confirmed the presence of elevated levels of arsenic, cobalt, copper, lead, nickel and silver in sediments and water of the Moira River system. Uranium is elevated in sediments in Young's Creek; however, the radioactivity from the amount of uranium present is the same as reference levels. Other radionuclides are not a concern at any location in the Moira River system.

2. Water quality has improved significantly over the past 35 years, in response to the cessation of processing activities and the ministry's cleanup activities at the mine site. Since the mid 1980s, arsenic, copper and nickel exceed the PWQO only at times of low river flow in the section of the river between the Deloro Mine Site and Bend Bay. For cobalt and lead, the PWQO is exceeded during low flow between the Deloro Mine Site and the outlet of Moira Lake.

3. Elevated concentrations of metals are present in sediments extending from below the Deloro Mine Site to downstream of Stoco Lake. The highest concentrations of metals are found in sediments in Young's Creek and in the deep basins of Bend Bay, Moira Lake and Stoco Lake.

4. Provincial Sediment Quality Guidelines (PSQG) are exceeded in the river system and for arsenic and nickel, these exceedances extend from the Deloro Mine Site through Moira and Stoco Lakes and further downstream.

5. Despite the exceedances of PWQOs during low flow and exceedances of PSQGs, no obvious adverse effects were observed in benthic invertebrates and fish populations in the Moira River, Moira Lake or Stoco Lake. Effects were observed on invertebrate abundance and species diversity in Young's Creek.

6. Cadmium, chromium, cobalt, lead and nickel do not represent a potential health risk to residents of the Moira River watershed and further assessment of the potential health risks posed by these metals is not required.

7. Exposure to arsenic in the Moira River downstream of Moira Lake is not expected to be greater than that of the Typical Ontario Resident (TOR), and further assessment of the potential health risks posed by this substance in these downstream areas is not warranted.

8. The reminder issued by the MOE and the Hastings and Prince Edward Counties Health Unit to residents of Study Areas A and B (from the Deloro Mine Site to the outlet of Moira Lake) advising them not to drink untreated surface water was, and continues to be, appropriate. The reminder is not only appropriate because of concerns about arsenic, but also because of the risk of exposure to pathogens in untreated water. If residents drink untreated water from the river or lake, they would have greater estimated levels of exposure to arsenic than the TOR under the conservative conditions assumed in this assessment. Where water is not used for drinking, arsenic is not a concern for residents and cottagers on Moira Lake.

9. Exposure to sediments in Study Area A during recreational use (wading or swimming) was identified as a potentially important exposure pathway. Further study was recommended. [This further study has since been conducted. The results show that exposure to the range of concentrations of arsenic detected in sediment in Study Area A will not result in adverse health effects after short-term or long-term exposure of area residents and other users of the river. Therefore, no specific risk management measures are required with respect to exposure to sediments in Study Area A.]

10. The concentrations of the metals of concern in fish fillets are below the levels that would require restrictions of fish consumption. However a fish consumption restriction for Moira and Stoco Lakes is in effect because of mercury; a substance not related to the Deloro Mine

Site. Consumption restrictions based on mercury are widespread throughout Ontario's lakes and rivers, including the reference lakes considered for this *Study*.

11. The water quality data suggest that there may be an additional, so far undefined source, of some metals to the Moira River, somewhere between the Deloro Mine Site and immediately below the confluence with Young's Creek.

12. The results of the predictive modelling indicated that the loading of arsenic and cobalt to the Moira River from the Deloro Mine Site would have to be essentially eliminated for downstream water quality to meet PWQOs. For arsenic, the interim PWQO of 5 micrograms per litre would not be met at Highway 7 during low flows even after 99% reduction; however it would be met year-round in Moira Lake and further downstream. The PWQO for cobalt would only be met below Moira Lake. Mean annual concentrations of nickel currently meet the PWQO; after cleanup, the PWQO would be met year round.

13. Sediment quality downstream from the Deloro Mine Site in the Moira River will continue to improve over the long term. However metal concentrations in sediment in the Moira River system down to and including Stoco Lake will remain above PSQGs for many years to come, independent of cleanup actions at the Deloro Mine Site.

14. The amount of metals reaching the Moira River from Young's Creek is relatively small compared to the amount from the Deloro Mine Site. However, the presence of a significant quantity of sediments retained behind a series of beaver dams is a concern. Should these dams fail, a significant quantity of sediments could be released to the Moira River.

Recommendations

1. The drinking water reminder to residents and cottagers in the Moira River watershed extending from the Deloro Mine Site to the outlet of Moira Lake not to use the river system as a source of drinking water should be continued.

2. The current monitoring programs for water quality and river flows conducted on behalf of or by the MOE should be continued.

3. Further assessment of the possible exposure of residents in Study Area A (Deloro Mine Site to the inlet of Moira Lake) to arsenic in sediments during recreational activities, is recommended. This assessment, an Updated PQRA, has since been conducted, the results of which have shown that further assessment of the potential health risks associated with arsenic in sediments in Study Area A is not warranted. The Updated PQRA reflects the conditions at the time of sediment sampling (August 2000). Should conditions change due to a major flood event, or in the event of a significant accidental release of sediments from Young's Creek, follow up sediment sampling would be recommended to confirm that exposure to sediments in Study Area A continues to represent no significant incremental health risk. In addition, sediment sampling following completion of the final cleanup program for the Deloro Mine Site, including Young's Creek, would also be appropriate.

4. An assessment of a possible source or sources of metals along the section of the Moira River between the Deloro Mine Site and immediately below the confluence with Young's Creek should be conducted. This assessment should include a review of mass loadings using the most recent water quality data.

5. As a precautionary measure, the public should be advised to avoid recreational activities in Young's Creek south of Highway 7 until such time as further characterization of sediment and water quality in this area has been completed. This characterization should also include an assessment of baseline biological conditions in Young's Creek including both aquatic and terrestrial resource components.

6. Subject to the results developed from the above recommendation, options to eliminate the likelihood of a release of sediments to the Moira River from Young's Creek should be evaluated and incorporated into the final cleanup plan for the Deloro Mine Site.

7. Development of the final cleanup plan for the Deloro Mine Site does not need to include consideration of effects in the downstream aquatic environment because benthic invertebrates and fish populations do not show adverse effects from the presence of metals in the Moira River system.

8. Development of the final cleanup plan for the Deloro Mine Site should include consideration of downstream water quality to reduce potential human health concerns associated with the presence of arsenic.

6. CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

GOLDER ASSOCIATES LTD.

John Petrie, M.Sc. Principal, Senior Hydrogeologist Project Manager	Stella Swanson, Ph.D., P.Biol. Associate Senior Aquatic Biologist

GLOBALTOX INTERNATIONAL CONSULTANTS INC.

Ronald Brecher, Ph.D., C.Chem, DABT
Principal

APPENDIX I

WATER QUALITY METHODS AND DATA

Appendix I.1 MOE Laboratory Services Branch Method References for Water Analysis

MOE Laboratory Services Branch (LSB) Method References for Water Analyses

E3089
THE DETERMINATION OF ARSENIC, SELENIUM AND ANTIMONY IN WATER BY HYDRIDE GENERATION-FLAMELESS ATOMIC ABSORPTION SPECTROPHOTOMETRY (HYD-FAAS)

E3386
THE DETERMINATION OF METALS IN SURFACE WATER BY INDUCTIVELY COUPLED PLASMA - ATOMIC EMISSION SPECTROSCOPY (ICP -AES) USING ULTRASONIC NEBULIZATION

E3210
THE DETERMINATION OF URANIUM IN SURFACE WATER BY ICP-MS

LSB Method Detection Limits

E3089

Element	Detection Limit	Units
As	0.5	ug/l

E3210

Element	Detection Limit	Units
U	0.1	ug/l

E3386

Element	Detection Limit	Units
Ag	0.4	ug/l
Al	1.3	ug/l
Co	0.7	ug/l
Cr	0.7	ug/l
Cu	0.3	ug/l
Ni	1.7	ug/l
Pb	8	ug/l
Zn	0.3	ug/l

Analysis Methods from the Radiation Protection Service, Ministry of Labour

Gross alpha and beta analysis is a general scan performed by a scintillation counter to indicate whether isotopes may be present. The isotopic composition of the sample was counted by gamma spectrometry. Instrumental energy calibration is regularly checked against mixed radionuclide gamma-ray reference sources prepared with solutions supplied by Amersham International and traceable to NIST by certificate of calibration. Detectors were standardized against a similar geometry spiked with mixed radionuclide gamma-ray reference solution supplied by Amersham International and traceable to NIST by certificate of calibration. In terms of quality assurance programs, the Radiation Protection Monitoring Service generates routine internal blind samples in all matrices analyzed and participates in Intercomparison Programs with the IAEA, the US. EPA (until the program was discontinued in late 1998) and the US Environmental Measurements Laboratory (since 1998).

Appendix I.2 Annual Mean Concentrations of Metals of Concern in the Moira River System and in Reference Lakes and Rivers

Figure I-1
Annual Mean Moira River Arsenic Levels (from Upstream to Downstream) (mg/L)

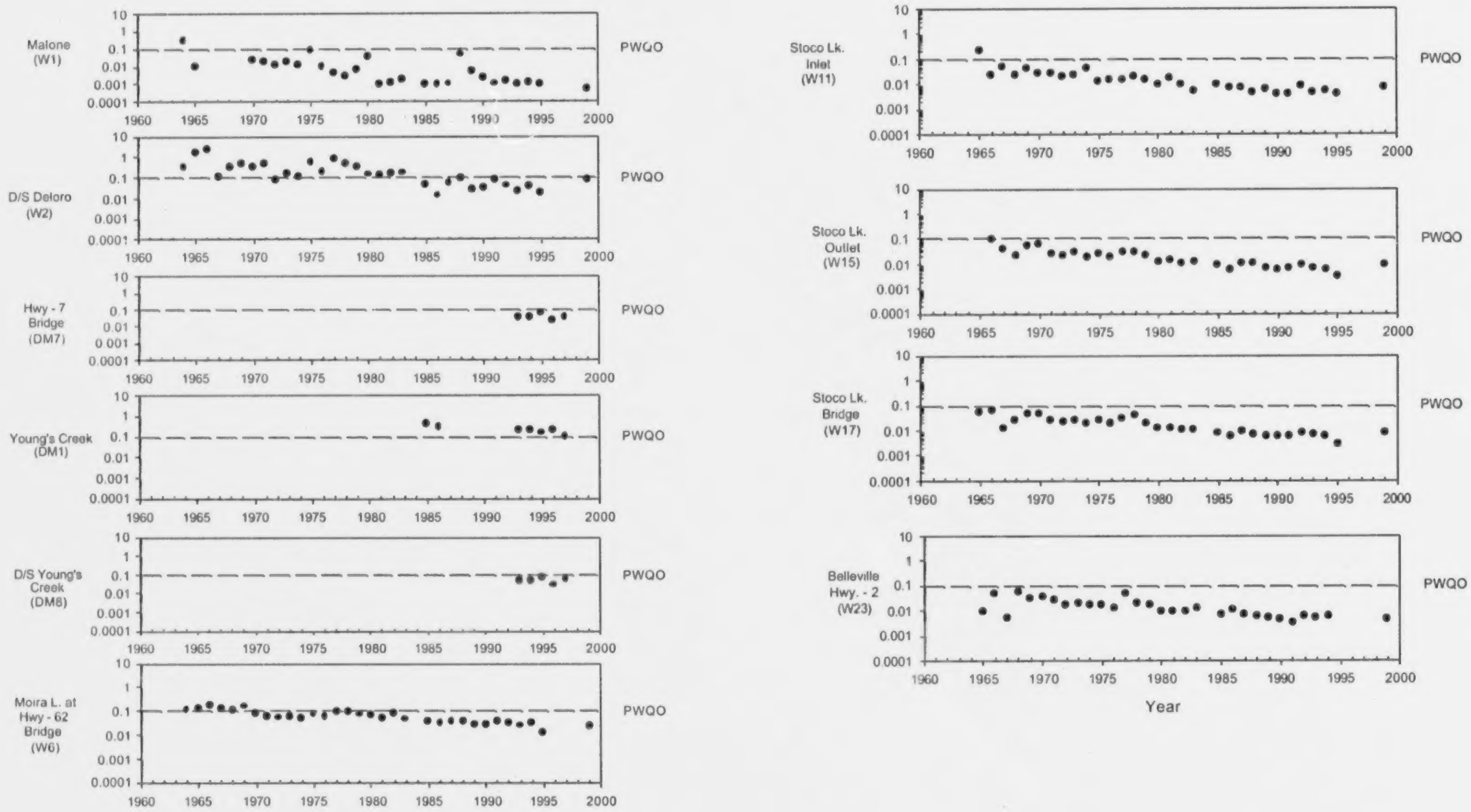


Figure I-2
Annual Mean Arsenic Levels from reference Rivers (mg/L)

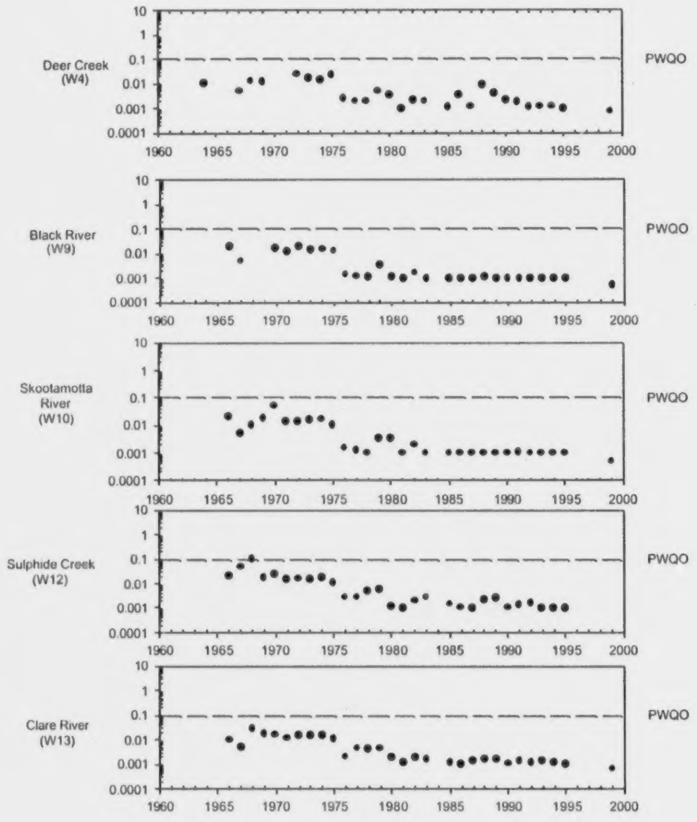


Figure I-3
Annual Mean Moira River Cobalt Levels (from Upstream to Downstream) (mg/L)

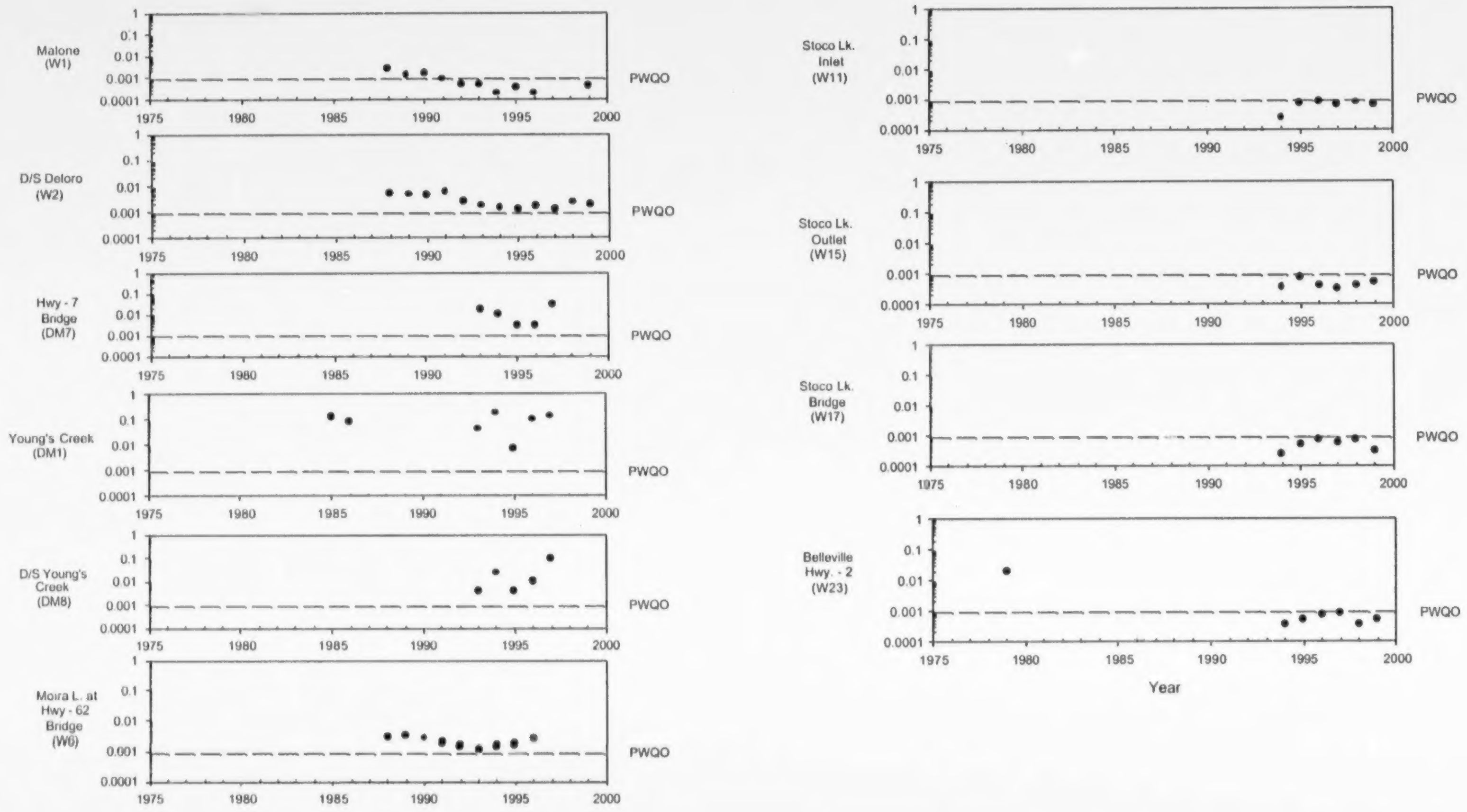


Figure I-4
Annual Mean Cobalt Levels from Reference Rivers (mg/L)

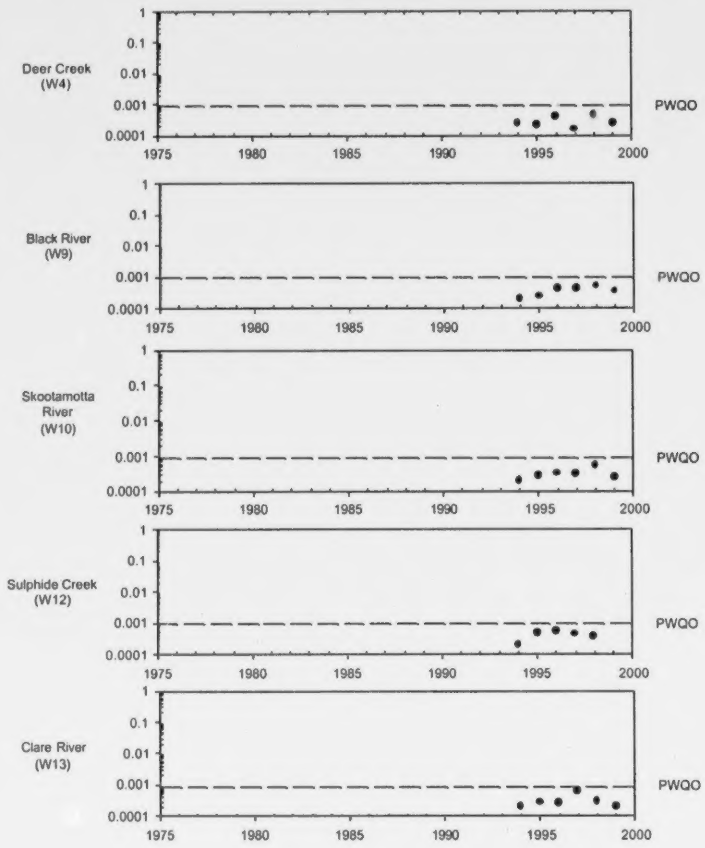


Figure I-5
Annual Mean Moira River Copper Levels (from Upstream to Downstream) (mg/L)

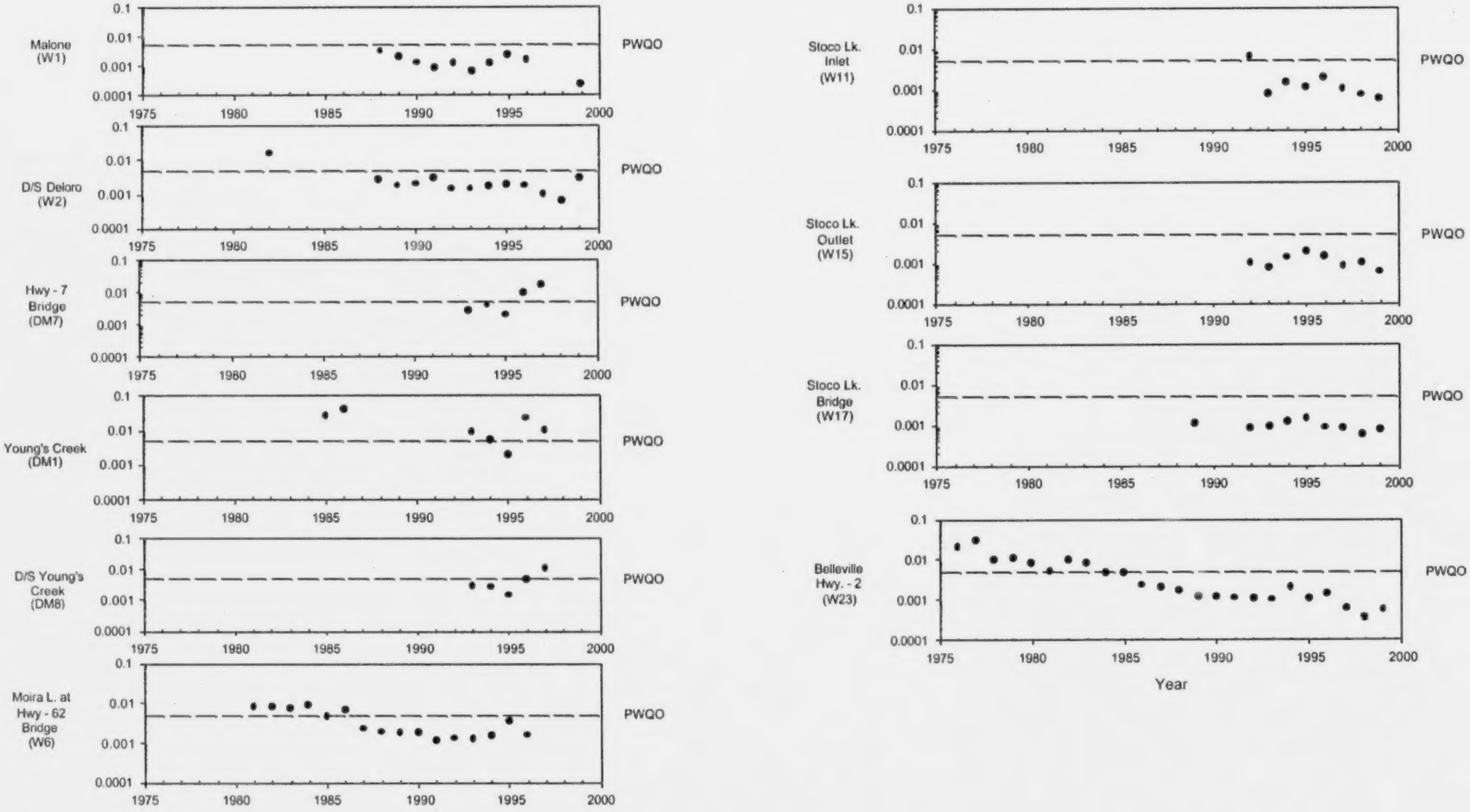


Figure I-6
Annual Mean Moira River Copper Levels from Reference Rivers (mg/L)

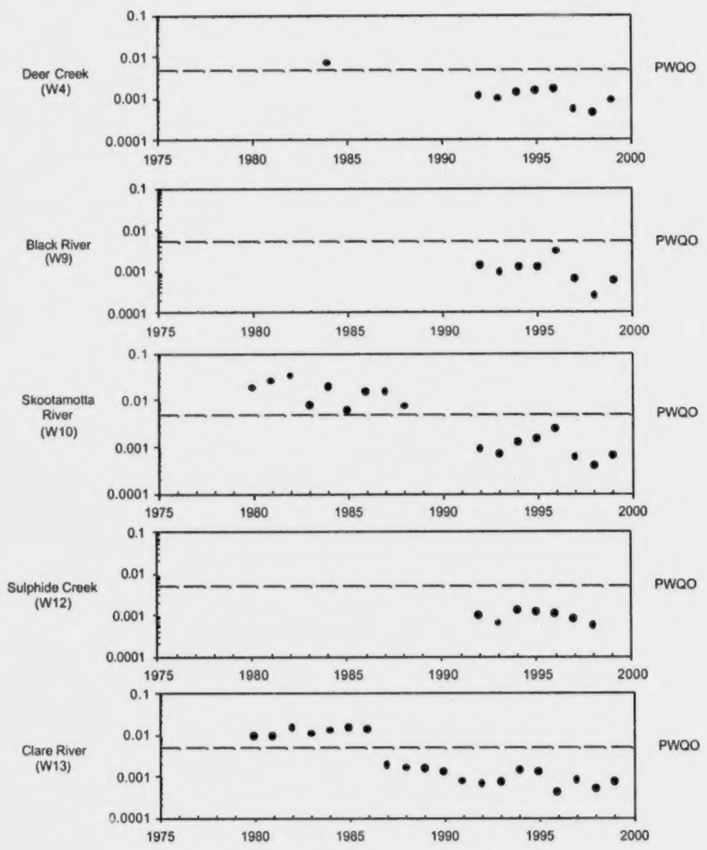


Figure I-7
Annual Mean Moira River Lead Levels (from Upstream to Downstream) (mg/L)

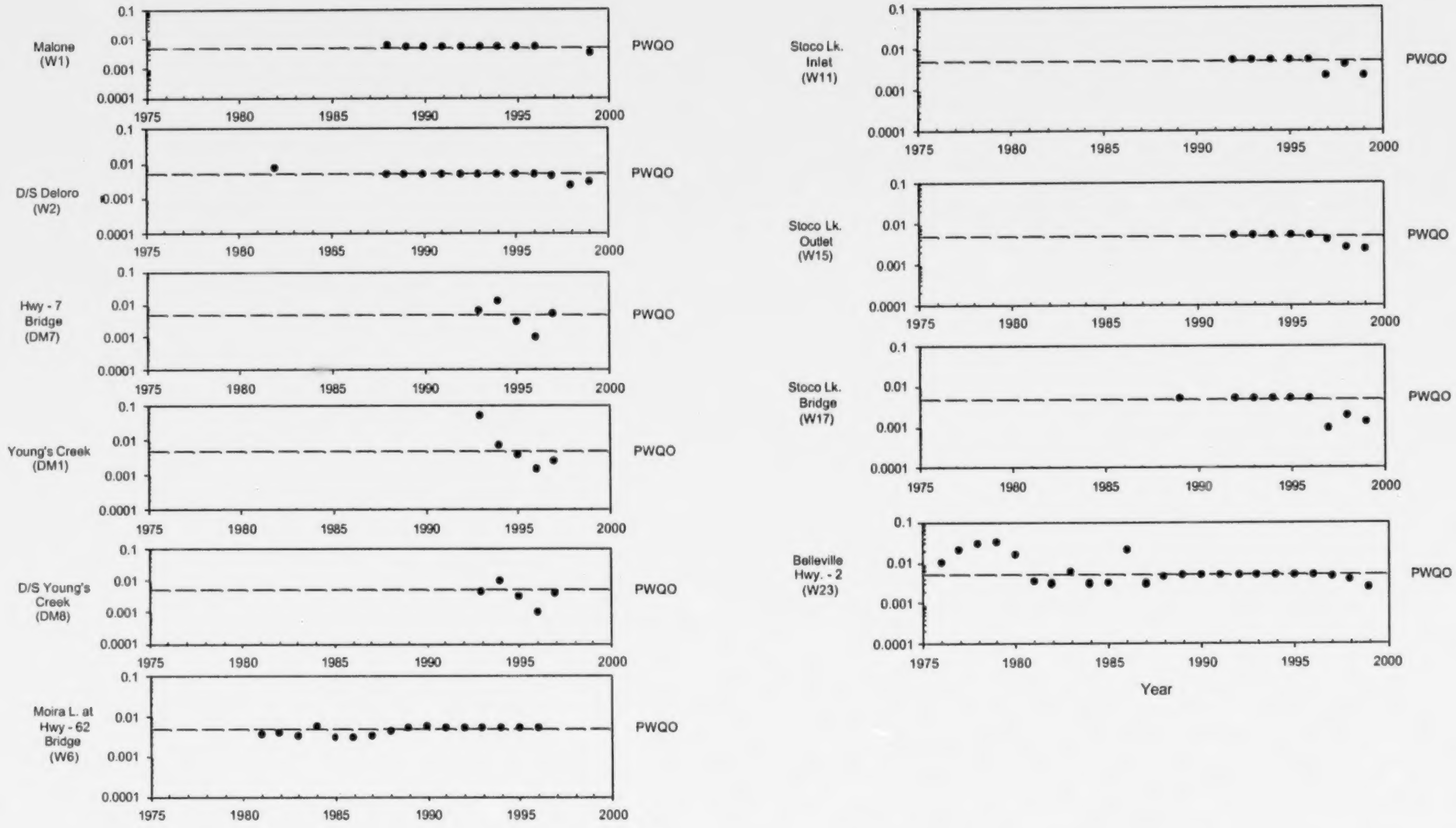


Figure I-8
Annual Mean Lead Levels from Reference Rivers (mg/L)

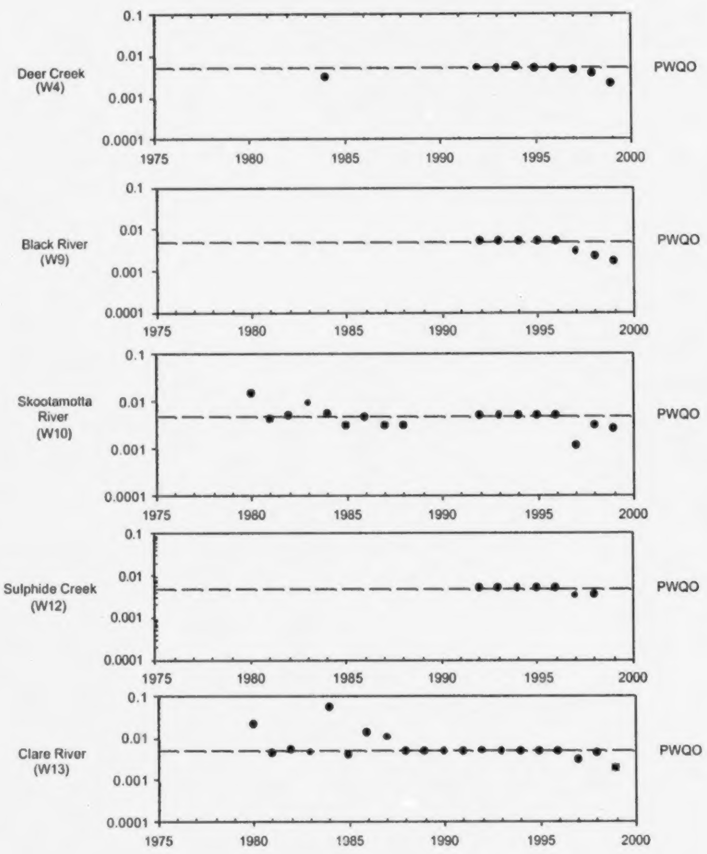


Figure I-9
Annual Mean Moira River Nickel Levels (from Upstream to Downstream) (mg/L)

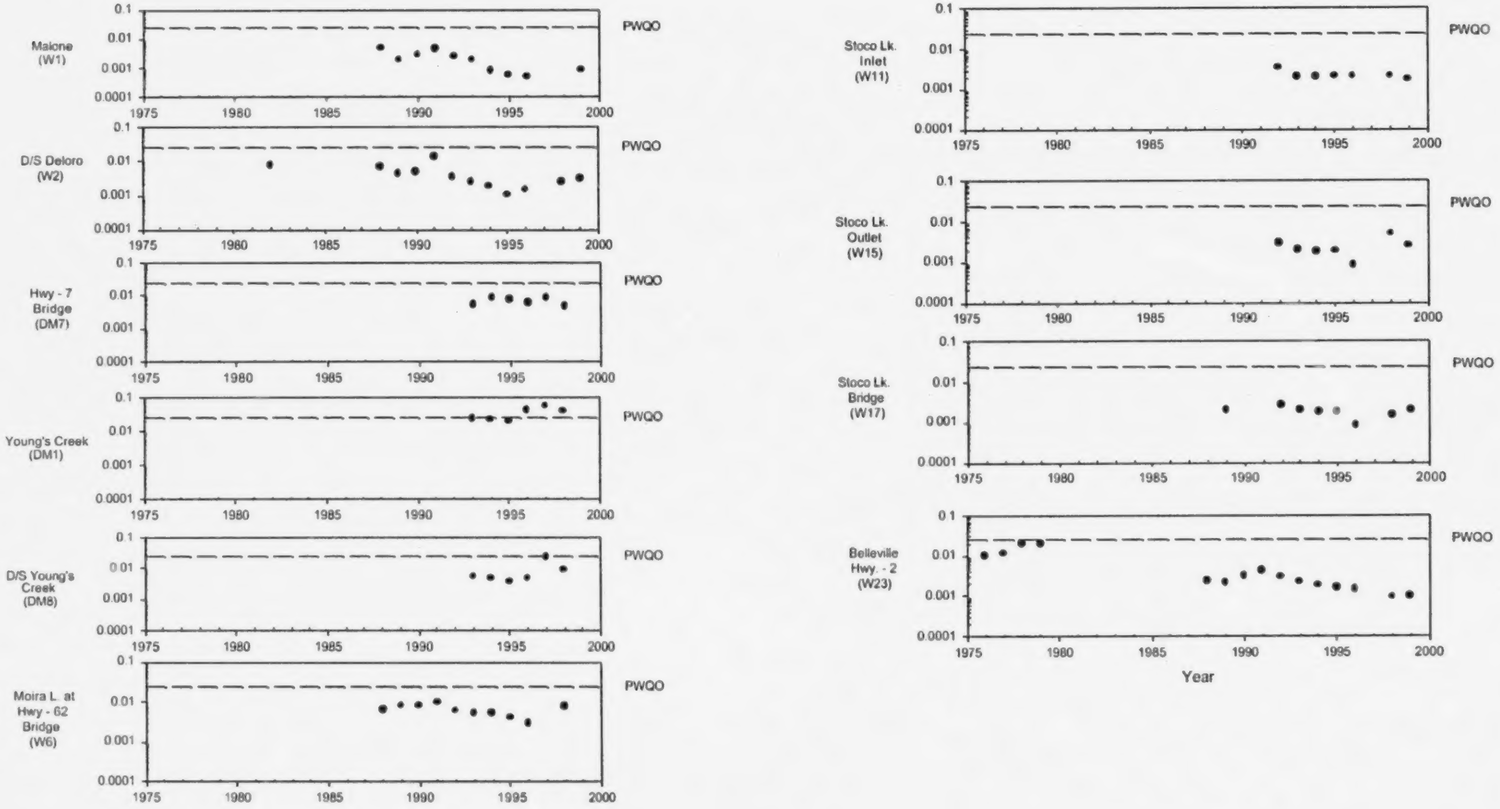
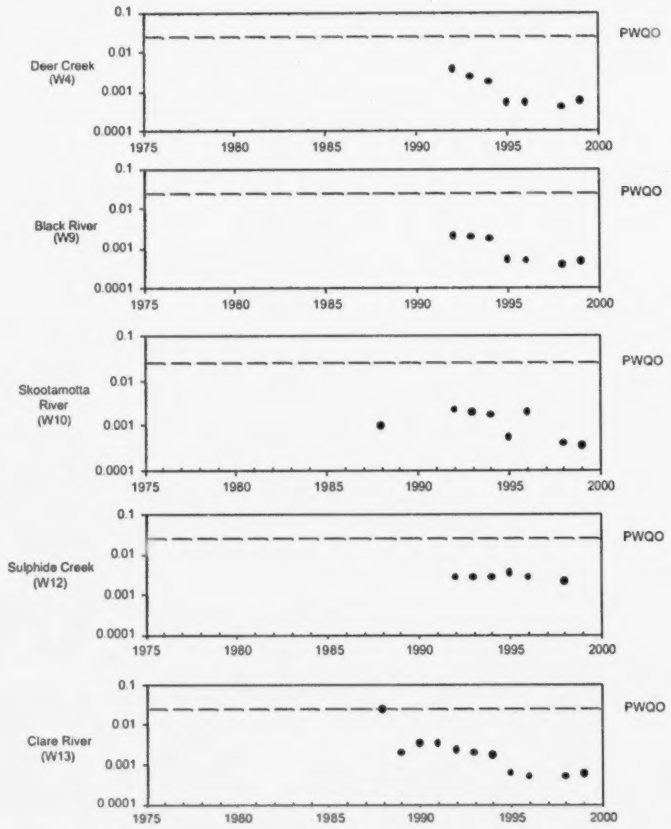


Figure I-10
Annual Mean Nickel Levels from Reference Rivers (mg/L)



Appendix I.3 Gross Alpha, Gross Beta and Radionuclide Activities in the Moira River System, 1999

Monthly Water Samples Submitted as Part of the MOE Moira River

Region: Eastern **Area: Moira R**

Smp No.	Sampling Date	Station No.	Location	Gross Alpha Bq/L	Gross Beta Bq/L	Ra-226 Bq/L	Ra-228 Bq/L	Th-228 Bq/L	U-238 Bq/L
001	19 Apr 99	C60531-0001	Moira R. West Channel 47990	<0.05	<0.05	<0.6	<1.0	<0.8	<5
002	19 Apr 99	C60531-0002	Moira R. East Channel 47901	<0.05	<0.05	<0.6	<1.0	<0.8	<5
003	19 Apr 99	C60531-0005	Stoco Lk Inlet 47903	<0.05	<0.05	<0.6	<1.0	<0.8	<5
004	19 Apr 99	C60531-0004	Moira Lk. Outlet 47904	<0.05	<0.05	<0.6	<1.0	<0.8	<5
005	19 Apr 99	C60531-0008	Moira R. Hwy 7 47907	<0.05	<0.05	<0.6	<1.0	<0.8	<5
006	19 Apr 99	C60531-0009	Upstream of Deloro 47908	<0.05	<0.05	<0.6	<1.0	<0.8	<5
007	19 Apr 99	C60531-0010	Moira Lk. Narrows 47910	<0.05	<0.05	<0.6	<1.0	<0.8	<5

Smp No.	Sampling Date	Station No.	Location	Gross Alpha Bq/L	Gross Beta Bq/L	Ra-226 Bq/L	Ra-228 Bq/L	Th-228 Bq/L	U-238 Bq/L
001	03 May 99	C60789-0001	Moira R. West Channel 47913	<0.05	0.06	<0.6	<1.0	<0.8	<5
002	03 May 99	C60789-0002	Moira R. East Channel 47914	<0.05	0.07	<0.6	<1.0	<0.8	<5
003	03 May 99	C60789-0005	Stoco Lk Inlet 47916	<0.05	0.06	<0.6	<1.0	<0.8	<5
004	03 May 99	C60789-0004	Moira Lk. Outlet 47917	<0.05	0.07	<0.6	<1.0	<0.8	<5
005	03 May 99	C60789-0008	Moira R. Hwy 7 47920	<0.05	0.06	<0.6	<1.0	<0.8	<5
006	03 May 99	C60789-0009	Upstream of Deloro 47921	<0.05	0.06	<0.6	<1.0	<0.8	<5
007	03 May 99	C60789-0011	Moira Lk. Narrows 47923	<0.05	0.06	<0.6	<1.0	<0.8	<5

Smp No.	Sampling Date	Station No.	Location	Gross Alpha Bq/L	Gross Beta Bq/L	Ra-226 Bq/L	Ra-228 Bq/L	Th-228 Bq/L	U-238 Bq/L
001	07 Jun 99	C62074-0001	Stoco Lk. Outlet W. 47926	<0.04	0.05	<0.1	<1	<1	<5
002	07 Jun 99	C62074-0002	Stoco Lk. Outlet E. 47937	<0.04	0.05	<0.1	<1	<1	<5
003	07 Jun 99	C62074-0005	Stoco Lk. Inlet Louisa St.	<0.04	<0.04	<0.1	<1	<1	<5
004	07 Jun 99	C62074-0004	Moira Lk. Outlet Rapids Rd.	<0.04	<0.04	<0.1	<1	<1	<5
005	07 Jun 99	C62074-0008	Hwy 7 Downstream of Deloro	<0.04	0.06	<0.1	<1	<1	<5
006	07 Jun 99	C62074-0009	Upstream of Deloro 47938	<0.04	0.06	<0.1	<1	<1	<5
007	07 Jun 99	C62074-0011	Moira Lk. Narrows Hwy. 62	<0.04	0.05	<0.1	<1	<1	<5

Smp No.	Sampling Date	Station No.	Location	Gross Alpha Bq/L	Gross Beta Bq/L	Ra-226 Bq/L	Ra-228 Bq/L	Th-228 Bq/L	U-238 Bq/L
001	11 Jul 99	003	Stoco Lk. Outlet West Channel	<0.04	0.04	<0.6	<1	<1	<5
002	11 Jul 99	004	Stoco Lk. Outlet East Channel	<0.04	0.04	<0.6	<1	<1	<5
003	11 Jul 99	023	Moira Lk. Rapids Rd.	<0.04	0.04	<0.6	<1	<1	<5
004	11 Jul 99	013	Hwy 7 Downstream of Deloro	<0.04	0.06	<0.6	<1	<1	<5
005	11 Jul 99	006	Stoco Lk. Louisa St.	<0.04	0.04	<0.6	<1	<1	<5
006	11 Jul 99	019	Malone Upstream of Deloro	<0.04	0.05	<0.6	<1	<1	<5
007	11 Jul 99	011	Moira Lk. Narrows Hwy. 62	<0.04	0.06	<0.6	<1	<1	<5

Smp No.	Sampling Date	Station No.	Location	Gross Alpha Bq/L	Gross Beta Bq/L	Ra-226 Bq/L	Ra-228 Bq/L	Th-228 Bq/L	U-238 Bq/L
001	12 Aug 99	47991	Stoco Lk. Outlet West Channel	<0.04	0.05	<0.6	<1	<0.8	<5
002	12 Aug 99	47992	Stoco Lk. Outlet East Channel	<0.04	0.05	<0.6	<1	<0.8	<5
003	12 Aug 99	47994	Stoco Lk. Inlet	<0.04	0.05	<0.6	<1	<0.8	<5
004	12 Aug 99	48001	Moira Lk. Narrows	<0.04	0.07	<0.6	<1	<0.8	<5
005	12 Aug 99	47998	Hwy 7 Downstream of Deloro	<0.04	0.06	<0.6	<1	<0.8	<5
006	12 Aug 99	47999	Upstream of Deloro	<0.04	0.05	<0.6	<1	<0.8	<5
007	12 Aug 99	47995	Moira Lk. Outlet	0.05	0.07	<0.6	<1	<0.8	<5

Smp No.	Sampling Date	Station No.	Location	Gross Alpha Bq/L	Gross Beta Bq/L	Ra-226 Bq/L	Ra-228 Bq/L	Th-228 Bq/L	U-238 Bq/L
001	23 Aug 99	47952	Moira R. West Channel	<0.04	0.05	<0.6	<1	<0.8	<5
002	23 Aug 99	47953	Moira R. East Channel	<0.04	0.07	<0.6	<1	<0.8	<5
003	23 Aug 99	47955	Stoco Lk. Inlet	<0.04	0.05	<0.6	<1	<0.8	<5
004	23 Aug 99	47956	Moira Lk. Outlet	<0.04	0.06	<0.6	<1	<0.8	<5
005	23 Aug 99	47959	Moira R. Hwy 7	<0.04	0.10	<0.6	<1	<0.8	<5
006	23 Aug 99	47960	Upstream of Deloro	<0.04	0.05	<0.6	<1	<0.8	<5
007	23 Aug 99	47962	Moira Lk. Narrows	<0.04	0.06	<0.6	<1	<0.8	<5

Smp No.	Sampling Date	Station No.	Location	Gross Alpha Bq/L	Gross Beta Bq/L	Ra-226 Bq/L	Ra-228 Bq/L	Th-228 Bq/L	U-238 Bq/L
001	12 Oct 99	003	Stoco Lk. Outlet West Channel	<0.04	0.06	<0.6	<1	<0.8	<5
002	12 Oct 99	004	Stoco Lk. Outlet East Channel	0.04	0.06	<0.6	<1	<0.8	<5
003	12 Oct 99	006	Stoco Lk. Inlet Louisa St.	<0.04	0.06	<0.6	<1	<0.8	<5
004	12 Oct 99	023	Moira Lk. Outlet Rapids Rd.	<0.04	0.10	<0.6	<1	<0.8	<5
005	12 Oct 99	013	Downstream of Hwy 7	<0.04	0.09	<0.6	<1	<0.8	<5
006	12 Oct 99	019	Malone Upstream of Deloro	<0.04	0.08	<0.6	<1	<0.8	<5
007	12 Oct 99	011	Moira Lk. Narrows Hwy. 62	<0.04	0.06	<0.6	<1	<0.8	<5

Smp No.	Sampling Date	Station No.	Location	Gross Alpha Bq/L	Gross Beta Bq/L	Ra-226 Bq/L	Ra-228 Bq/L	Th-228 Bq/L	U-238 Bq/L
001	16 Nov 99	003	Stoco Lk. Outlet West Channel	<0.04	0.06	<0.6	<1	<0.8	<5
002	16 Nov 99	004	Stoco Lk. Outlet East Channel	<0.04	0.06	<0.6	<1	<0.8	<5
003	16 Nov 99	006	Stoco Lk. Inlet Louisa St.	<0.04	0.06	<0.6	<1	<0.8	<5
004	16 Nov 99	011	Moira Lk. Narrows Hwy. 62	<0.04	0.05	<0.6	<1	<0.8	<5
005	16 Nov 99	013	Moira R. Hwy 7 Downstream	<0.04	0.06	<0.6	<1	<0.8	<5
006	16 Nov 99	019	Malone Upstream of Deloro	<0.04	0.05	<0.6	<1	<0.8	<5
007	16 Nov 99	023	Moira Lk. Outlet Rapids Rd.	<0.04	0.07	<0.6	<1	<0.8	<5

Smp No.	Sampling Date	Station No.	Location	Gross Alpha Bq/L	Gross Beta Bq/L	Ra-226 Bq/L	Ra-228 Bq/L	Th-228 Bq/L	U-238 Bq/L
001	10 Jan 00	C68816-0002	Moira R. Stoco Bridge	<0.04	0.05	<0.6	<1	<0.8	<5
002	10 Jan 00	C68816-0004	Moira R. Outlet at Rapid Rd.	<0.04	0.06	<0.6	<1	<0.8	<5
003	10 Jan 00	C68816-0005	Louisa St. -Tweed	<0.04	0.05	<0.6	<1	<0.8	<5
004	10 Jan 00	C68816-0008	Moira R. Hwy 7 Deloro	0.04	0.08	<0.6	<1	<0.8	<5
005	10 Jan 00	C68816-0009	Moira R. Malone	<0.04	0.07	<0.6	<1	<0.8	<5
006	10 Jan 00	C68816-0011	Moira Lk. Hwy 62	<0.04	<0.04	<0.6	<1	<0.8	<5

Smp No.	Sampling Date	Station No.	Location	Gross Alpha Bq/L	Gross Beta Bq/L	Ra-226 Bq/L	Ra-228 Bq/L	Th-228 Bq/L	U-238 Bq/L
001	08 Feb 00	003	Stoco Lk. Outlet West Channel	<0.04	0.05	<0.6	<1	<0.8	<5
002	08 Feb 00	004	Stoco Lk. Outlet East Channel	<0.04	0.06	<0.6	<1	<0.8	<5
003	08 Feb 00	006	Stoco Lk. Inlet Louisa St.	<0.04	0.08	<0.6	<1	<0.8	<5
004	08 Feb 00	011	Moira Lk. Narrows Hwy. 62	<0.04	0.07	<0.6	<1	<0.8	<5
005	08 Feb 00	013	Moira R. Hwy 7 Downstream	<0.04	0.07	<0.6	<1	<0.8	<5
006	08 Feb 00	019	Malone Upstream of Deloro	<0.04	0.07	<0.6	<1	<0.8	<5
007	08 Feb 00	023	Moira Lk. Outlet Rapids Rd.	<0.04	0.06	<0.6	<1	<0.8	<5

Smp No.	Sampling Date	Station No.	Location	Gross Alpha Bq/L	Gross Beta Bq/L	Ra-226 Bq/L	Ra-228 Bq/L	Th-228 Bq/L	U-238 Bq/L
001	27 Mar 00	003	Stoco Lk. Outlet West Channel	<0.04	0.06	<0.6	<1	<0.8	<5
002	27 Mar 00	004	Stoco Lk. Outlet East Channel	<0.04	0.05	<0.6	<1	<0.8	<5
003	27 Mar 00	006	Stoco Lk. Inlet Louisa St.	<0.04	0.06	<0.6	<1	<0.8	<5
004	27 Mar 00	011	Moira Lk. Narrows Hwy. 62	<0.04	0.06	<0.6	<1	<0.8	<5
005	27 Mar 00	013	Moira R. Hwy 7 Downstream	<0.04	0.06	<0.6	<1	<0.8	<5
006	27 Mar 00	019	Malone Upstream of Deloro	<0.04	0.06	<0.6	<1	<0.8	<5
007	27 Mar 00	023	Moira Lk. Outlet Rapids Rd.	<0.04	0.07	<0.6	<1	<0.8	<5

Smp No.	Sampling Date	Station No.	Location	Gross Alpha Bq/L	Gross Beta Bq/L	Ra-226 Bq/L	Ra-228 Bq/L	Th-228 Bq/L	U-238 Bq/L
001	25 Apr 00	003	Stoco Lk. Outlet West Channel	<0.04	0.05	<0.6	<1	<0.8	<5
002	25 Apr 00	004	Stoco Lk. Outlet East Channel	<0.04	0.04	<0.6	<1	<0.8	<5
003	25 Apr 00	006	Stoco Lk. Inlet Louisa St.	<0.04	0.05	<0.6	<1	<0.8	<5
004	25 Apr 00	011	Moira Lk. Narrows Hwy. 62	<0.04	0.05	<0.6	<1	<0.8	<5
005	25 Apr 00	013	Moira R. Hwy 7 Downstream	<0.04	0.05	<0.6	<1	<0.8	<5
006	25 Apr 00	019	Malone Upstream of Deloro	<0.04	0.05	<0.6	<1	<0.8	<5
007	25 Apr 00	023	Moira Lk. Outlet Rapids Rd.	<0.04	0.05	<0.6	<1	<0.8	<5

STAT-1 (04/92)

LIMIT OF DETECTION AND ERROR DETERMINATION IN GROSS ALPHA AND BETA

Limit of Detection

$L_d(\text{counts}) = 2.71 + 4.65 \times (R_b \times T)^{1/2}$

$L_d(\text{cpm}) = L_d(\text{counts})/T$

$L_d(\text{mBq/L}) = L_d(\text{cpm}) \times 1000 \times W1/(60 \times E \times W_2 \times V)$

Where R_b = count rate background
T = total counting time in minutes
E = counting efficiency
W_1 = weight of solids
W_2 = weight of solids taken for counting
V = sample volume in litres

Counting Error Calculation

$s_s\ (\text{cpm}) = (R_{s+b}/T_s + R_b/T_b)^{1/2}$

Where R_{s+b} = gross count rate for sample
Rb = count rate for background
T_s = counting time for sample (minutes)
T_b = counting time for background (minutes)
s_s = standard deviation of net count rate of sample

Counting Error in Sample Activity

$RE(\text{mBq/L}) = s_s \times \text{sample activity} / R_s$

Where R_s = net count rate for sample

Practical Limit of detection for Alpha = .04 Bq/L

Practical Limit of detection for Beta = .04 Bq/L

Ontario Ministry of Labour
Radiation Protection Service Laboratory

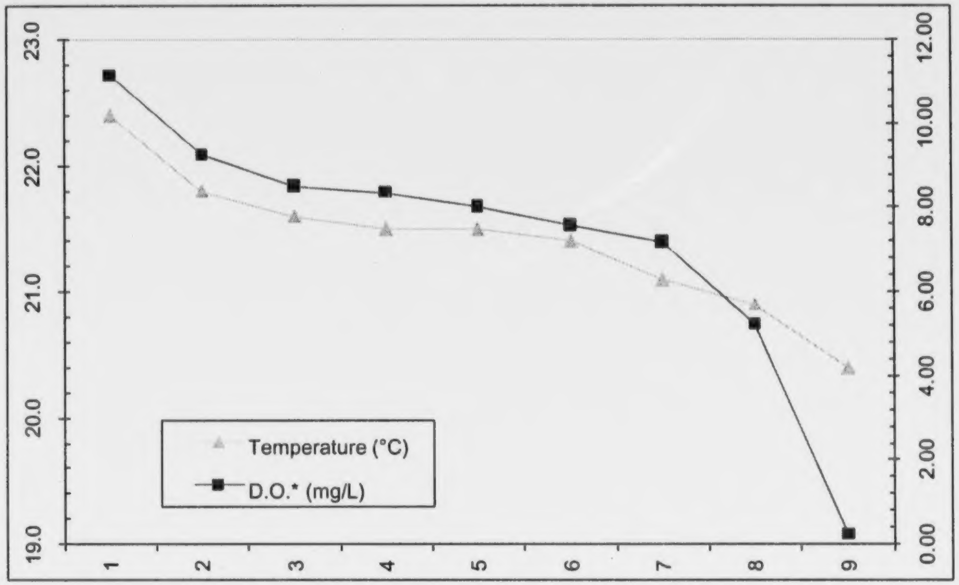
Appendix I.4 Dissolved Oxygen and Temperature Profiles in Moira Lake, Stoco Lake, Round Land and Consecon Lake

Dissolved Oxygen and Temperature Profile at Deepest Point in **Moira Lake**

Location: 44° 28.51' N
77° 27.36'W
Date: 31-Aug-99
Station: 3
Project #: 991-1358

Depth (m below surface)	D.O.* (mg/L)	Temperature (°C)
1	11.14	22.4
2	9.25	21.8
3	8.50	21.6
4	8.36	21.5
5	8.03	21.5
6	7.57	21.4
7	7.17	21.1
8	5.22	20.9
9	0.22	20.4

Approximate maximum depth 9m
Soft mud substrate



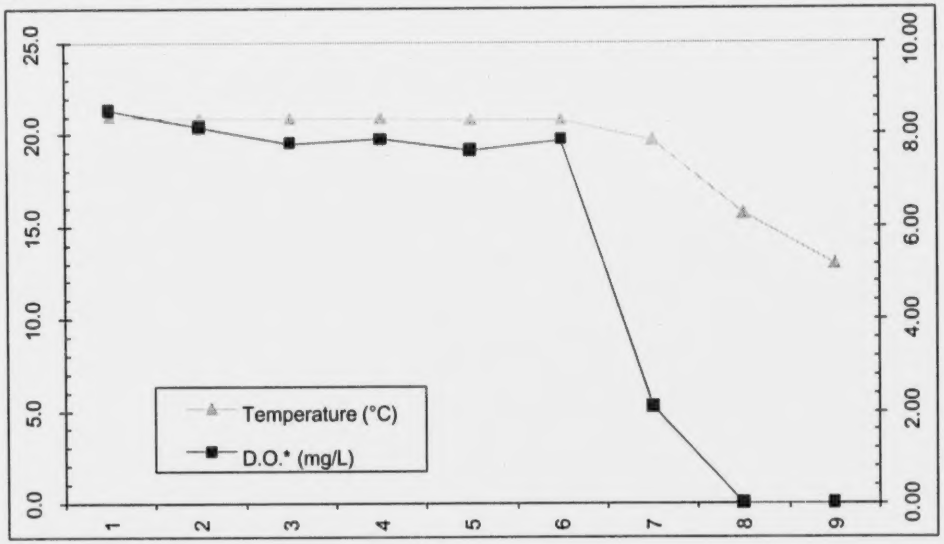
* D.O. measured with a WTW Microprocessor Pocket Oxygen Meter (Oxi 330/set)

Dissolved Oxygen and Temperature Profile at Deepest Point in **Stoco Lake**

Location:	44° 28.15' N	Date:	31-Aug-99
	77° 17.24'W	Station:	2
		Project #:	**991-1358**

Depth (m below surface)	D.O.* (mg/L)	Temperature (°C)
1	8.54	21.0
2	8.17	20.9
3	7.81	20.9
4	7.89	20.9
5	7.65	20.8
6	7.88	20.8
7	2.09	19.7
8	0.00	15.7
8.5	0.00	13.0

Maximum depth 8.5m
Muddy substrate



* D.O. measured with a WTW Microprocessor Pocket Oxygen Meter (Oxi 330/set)

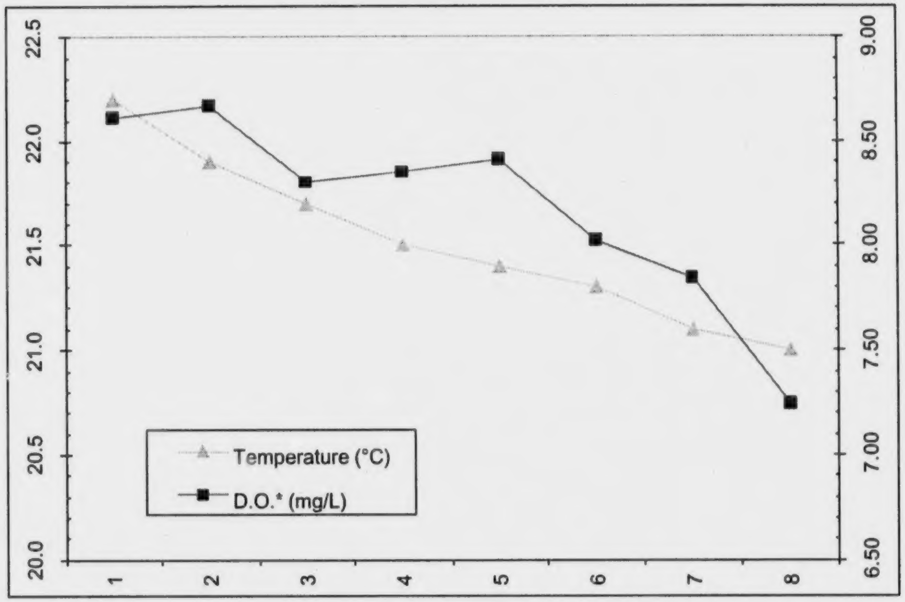
Dissolved Oxygen and Temperature Profile at Deepest Point in **Round Lake**

Location:	44° 29.62' N	Date:	31-Aug-99
	77° 52.45'W	Station:	4
		Project #:	**991-1358**

Depth (m below surface)	D.O.* (mg/L)	Temperature (°C)
1	8.61	22.2
2	8.67	21.9
3	8.30	21.7
4	8.35	21.5
5	8.41	21.4
6	8.02	21.3
7	7.84	21.1
8	7.24	21.0

Maximum depth: 8.7 m

Soft mud substrate



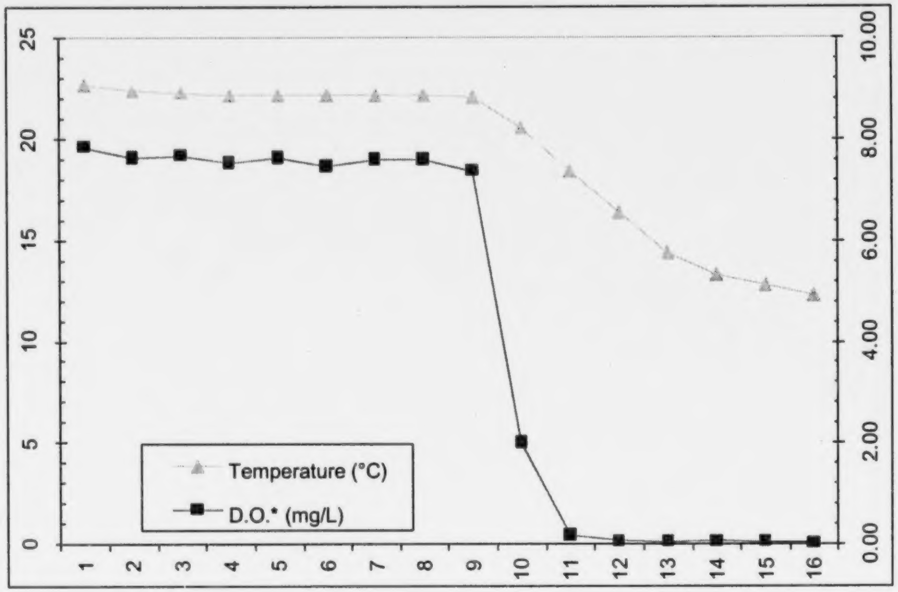
* D.O. measured with a WTW Microprocessor Pocket Oxygen Meter (Oxi 330/set)

Dissolved Oxygen and Temperature Profile at Deepest Point in **Consecon Lake**

Location: 44° 00.34' N
77° 27.25'W

Date: 30-Aug-99
Station: 1
Project #: 991-1358

Depth (m below surface)	D.O.* (mg/L)	Temperature (°C)
1	7.85	22.7
2	7.63	22.4
3	7.68	22.3
4	7.53	22.2
5	7.63	22.2
6	7.46	22.2
7	7.59	22.2
8	7.60	22.2
9	7.38	22.1
10	2.01	20.6
11	0.16	18.4
12	0.05	16.4
13	0.04	14.4
14	0.05	13.3
15	0.04	12.8
16	0.02	12.3



Maximum depth: 16.6 m

* D.O. measured with a WTW Microprocessor Pocket Oxygen Meter (Oxi 330/set)

Appendix I.5 Provincial Water Quality Network Data

Annual Mean Concentration of Metals of Concern for Moira River and Tributaries
(Data from MOE Provincial Water Quality Monitoring Network)

PDESC	Year	UNITS	OWQO	Units	Lily Cr	Deer Cr	Madoc Cr	Black R	Skootamatta R	Sulphide Cr	Clare R	Palliser Cr Quinte	Palliser Cr Foxborough	Malone	Moira HWY-7 (D/S Deloro)	Moira HWY-7	Young's Creek
ARSENIC, UNFILTERED TOTAL	1964	mg/L	0.1	mg/L		0.01								**0.3**	**0.32**		
ARSENIC, UNFILTERED TOTAL	1965	mg/L	0.1	mg/L			0.05							0.01	**1.72**		
ARSENIC, UNFILTERED TOTAL	1966	mg/L	0.1	mg/L				0.02	0.02	0.02	0.01				**2.5**		
ARSENIC, UNFILTERED TOTAL	1967	mg/L	0.1	mg/L		0.005		0.005	0.005	0.05	0.005				**0.11**		
ARSENIC, UNFILTERED TOTAL	1968	mg/L	0.1	mg/L		0.01			0.01	0.1	0.03				**0.34**		
ARSENIC, UNFILTERED TOTAL	1969	mg/L	0.1	mg/L		0.0125	0.03		0.018	0.02	0.02				**0.45**		
ARSENIC, UNFILTERED TOTAL	1970	mg/L	0.1	mg/L			0.02	0.02	0.05	0.02	0.02			0.02	**0.32**		
ARSENIC, UNFILTERED TOTAL	1971	mg/L	0.1	mg/L			0.02	0.0125	0.01	0.01	0.012			0.02	**0.51**		
ARSENIC, UNFILTERED TOTAL	1972	mg/L	0.1	mg/L		0.03		0.02	0.01	0.02	0.01			0.01	0.07		
ARSENIC, UNFILTERED TOTAL	1973	mg/L	0.1	mg/L		0.02		0.01	0.02	0.01	0.02			0.02	**0.17**		
ARSENIC, UNFILTERED TOTAL	1974	mg/L	0.1	mg/L		0.015		0.02	0.02	0.02	0.02			0.01	**0.12**		
ARSENIC, UNFILTERED TOTAL	1975	mg/L	0.1	mg/L		0.02		0.01	0.01	0.01	0.01			0.08	**0.57**		
ARSENIC, UNFILTERED TOTAL	1976	mg/L	0.1	mg/L		0.00		0.00	0.00	0.003	0.002			0.01	**0.19**		
ARSENIC, UNFILTERED TOTAL	1977	mg/L	0.1	mg/L		0.00		0.0012	0.00	0.003	0.005			0.004	**0.88**		
ARSENIC, UNFILTERED TOTAL	1978	mg/L	0.1	mg/L		0.00		0.00	0.001	0.005	0.004			0.003	**0.46**		
ARSENIC, UNFILTERED TOTAL	1979	mg/L	0.1	mg/L		0.01		0.00	0.00	0.01	0.005			0.01	**0.35**		
ARSENIC, UNFILTERED TOTAL	1980	mg/L	0.1	mg/L		0.00		0.00	0.00	0.001	0.002			0.04	**0.15**		
ARSENIC, UNFILTERED TOTAL	1981	mg/L	0.1	mg/L		0.001		0.001	0.001	0.001	0.001			0.001	**0.14**		
ARSENIC, UNFILTERED TOTAL	1982	mg/L	0.1	mg/L		0.002		0.002	0.002	0.002	0.002			0.001	**0.16**		
ARSENIC, UNFILTERED TOTAL	1983	mg/L	0.1	mg/L		0.002		0.001	0.001	0.003	0.002			0.002	**0.18**		
ARSENIC, UNFILTERED TOTAL	1984	mg/L	0.1	mg/L		0.001		0.001	0.001	0.001	0.001			0.001	0.069		
ARSENIC, UNFILTERED TOTAL	1985	mg/L	0.1	mg/L		0.001		0.001	0.001	0.001	0.001			0.001	0.05		**0.46**
ARSENIC, UNFILTERED TOTAL	1986	mg/L	0.1	mg/L		0.003		0.001	0.001	0.0011	0.001			0.001	0.01		**0.30**
ARSENIC, UNFILTERED TOTAL	1987	mg/L	0.1	mg/L		0.001		0.001	0.001	0.001	0.001			0.001	0.05		
ARSENIC, UNFILTERED TOTAL	1988	mg/L	0.1	mg/L		0.01		0.001	0.001	0.002	0.002			0.05	0.10		
ARSENIC, UNFILTERED TOTAL	1989	mg/L	0.1	mg/L		0.004		0.001	0.001	0.003	0.002			0.01	0.03		
ARSENIC, UNFILTERED TOTAL	1990	mg/L	0.1	mg/L		0.002		0.001	0.001	0.001	0.001			0.002	0.03		

PDESC	Year	UNITS	OWQO	Units	Lily Cr	Deer Cr	Madoc Cr	Black R	Skootamatta R	Sulphide Cr	Clare R	Palliser Cr Quinte	Palliser Cr Foxborough	Malone	Moira HWY-7 (D/S Deloro)	Moira HWY-7	Young's Creek
ARSENIC, UNFILTERED TOTAL	1991	mg/L	0.1	mg/L		0.002		0.001	0.00	0.001	0.001			0.001	0.08		
ARSENIC, UNFILTERED TOTAL	1992	mg/L	0.1	mg/L		0.001		0.001	0.001	0.002	0.001			0.0015	0.04		
ARSENIC, UNFILTERED TOTAL	1993	mg/L	0.1	mg/L		0.001		0.001	0.001	0.001	0.001			0.001	0.02	0.04	**0.20**
ARSENIC, UNFILTERED TOTAL	1994	mg/L	0.1	mg/L		0.0012		0.001	0.001	0.001	0.0012			0.0013	0.04	0.03	**0.20**
ARSENIC, UNFILTERED TOTAL	1995	mg/L	0.1	mg/L		0.001		0.001	0.001	0.001	0.001			0.001	0.019	0.06	**0.16**
ARSENIC, UNFILTERED TOTAL	1996	mg/L	0.1	mg/L												0.02	**0.19**
ARSENIC, UNFILTERED TOTAL	1997	mg/L	0.1	mg/L												0.03	0.10
ARSENIC, UNFILTERED TOTAL	1999	mg/L	0.1	mg/L		0.00075		0.0005	0.0005		0.0007			0.0005	0.08		

PDESC	Year	UNITS	OWQO	Units	Moira D/S Young's Creek	HWY 62 Bridge	Moira Lk Narrows	Moira Lk Outlet	Stoco Lk Inlet	Beach at Tweed	Stoco Lk Outlet	Chapmans BRG	Stoco BRG	Cannifton	Belleville CNR BRG	Belleville HWY-2	Belleville Victoria St
ARSENIC, UNFILTERED TOTAL	1964	mg/L	0.1	mg/L		**0.12**											
ARSENIC, UNFILTERED TOTAL	1965	mg/L	0.1	mg/L		**0.13**			**0.24**			0.04	0.05	0.03	0.04	0.01	0.02
ARSENIC, UNFILTERED TOTAL	1966	mg/L	0.1	mg/L		**0.18**			0.024		0.1		0.06	0.04		0.053	
ARSENIC, UNFILTERED TOTAL	1967	mg/L	0.1	mg/L		**0.13**			0.05		0.038		0.0125	0.005	0.005	0.005	
ARSENIC, UNFILTERED TOTAL	1968	mg/L	0.1	mg/L		**0.11**			0.02		0.022		0.026	0.01	0.05	0.06	
ARSENIC, UNFILTERED TOTAL	1969	mg/L	0.1	mg/L		**0.16**			0.04	0.05	0.05		0.051	0.04	0.03	0.033	
ARSENIC, UNFILTERED TOTAL	1970	mg/L	0.1	mg/L		0.08			0.03	0.04	0.06		0.04	0.036	0.03	0.034	
ARSENIC, UNFILTERED TOTAL	1971	mg/L	0.1	mg/L		0.06			0.03	0.03	0.03		0.02	0.02	0.01	0.03	
ARSENIC, UNFILTERED TOTAL	1972	mg/L	0.1	mg/L		0.055			0.02	0.03	0.02		0.02	0.02		0.02	
ARSENIC, UNFILTERED TOTAL	1973	mg/L	0.1	mg/L		0.06			0.024		0.03		0.03	0.02		0.02	
ARSENIC, UNFILTERED TOTAL	1974	mg/L	0.1	mg/L		0.05			0.04		0.02		0.02	0.02		0.02	
ARSENIC, UNFILTERED TOTAL	1975	mg/L	0.1	mg/L		0.08			0.01		0.03		0.02	0.02		0.02	
ARSENIC, UNFILTERED TOTAL	1976	mg/L	0.1	mg/L		0.06			0.01		0.02		0.02	0.01		0.01	
ARSENIC, UNFILTERED TOTAL	1977	mg/L	0.1	mg/L		0.10			0.02		0.03		0.03	0.017		0.053	
ARSENIC, UNFILTERED TOTAL	1978	mg/L	0.1	mg/L		0.10			0.02	0.03	0.03		0.04	0.02		0.02	
ARSENIC, UNFILTERED TOTAL	1979	mg/L	0.1	mg/L		0.08			0.02	0.02	0.02		0.02	0.02		0.02	
ARSENIC, UNFILTERED TOTAL	1980	mg/L	0.1	mg/L		0.07			0.01		0.01		0.01	0.03		0.01	
ARSENIC, UNFILTERED TOTAL	1981	mg/L	0.1	mg/L		0.05			0.02		0.01		0.01	0.01		0.01	

PDESC	Year	UNITS	OWQO	Units	Moira D/S Young's Creek	HWY 62 Bridge	Moira Lk Narrows	Moira Lk Outlet	Stoco Lk Inlet	Beach at Tweed	Stoco Lk Outlet	Chapmans BRG	Stoco BRG	Cannifton	Belleville CNR BRG	Belleville HWY-2	Belleville Victoria St
ARSENIC, UNFILTERED TOTAL	1982	mg/L	0.1	mg/L		0.08			0.01		0.01		0.01	0.01		0.01	
ARSENIC, UNFILTERED TOTAL	1983	mg/L	0.1	mg/L		0.05			0.01		0.01		0.01	0.01		0.01	
ARSENIC, UNFILTERED TOTAL	1984	mg/L	0.1	mg/L		0.04			0.01		0.011	0.001	0.01	0.01		0.01	
ARSENIC, UNFILTERED TOTAL	1985	mg/L	0.1	mg/L		0.04			0.01		0.01		0.01	0.01		0.01	
ARSENIC, UNFILTERED TOTAL	1986	mg/L	0.1	mg/L		0.03			0.01		0.006		0.01	0.01		0.01	
ARSENIC, UNFILTERED TOTAL	1987	mg/L	0.1	mg/L		0.04			0.01		0.01		0.01	0.01		0.01	0.0012
ARSENIC, UNFILTERED TOTAL	1988	mg/L	0.1	mg/L		0.04			0.005		0.01		0.01	0.01		0.01	0.001
ARSENIC, UNFILTERED TOTAL	1989	mg/L	0.1	mg/L		0.03			0.01		0.007		0.01	0.01		0.01	0.001
ARSENIC, UNFILTERED TOTAL	1990	mg/L	0.1	mg/L		0.03			0.004		0.01		0.01	0.004		0.004	0.001
ARSENIC, UNFILTERED TOTAL	1991	mg/L	0.1	mg/L		0.04			0.004		0.0065		0.01	0.003		0.003	0.001
ARSENIC, UNFILTERED TOTAL	1992	mg/L	0.1	mg/L		0.03			0.01		0.01		0.01	0.0045		0.01	0.001
ARSENIC, UNFILTERED TOTAL	1993	mg/L	0.1	mg/L	0.05	0.03			0.005		0.01		0.01	0.01		0.01	0.001
ARSENIC, UNFILTERED TOTAL	1994	mg/L	0.1	mg/L	0.05	0.03			0.01		0.01		0.01	0.01		0.01	0.001
ARSENIC, UNFILTERED TOTAL	1995	mg/L	0.1	mg/L	0.07	0.01			0.004		0.003		0.003				0.001
ARSENIC, UNFILTERED TOTAL	1996	mg/L	0.1	mg/L	0.03												
ARSENIC, UNFILTERED TOTAL	1997	mg/L	0.1	mg/L	0.06												
ARSENIC, UNFILTERED TOTAL	1999	mg/L	0.1	mg/L		0.025	0.028	0.016	0.0075		0.0091		0.0082	0.0041		0.0044	0.0007

PDESC	Year	UNITS	OWQO	Units	Lily Cr	Deer Cr	Madoc Cr	Black R	Skootamatta R	Sulphide Cr	Clare R	Palliser Cr Quinte	Palliser Cr Foxborough	Malone	Moira HWY-7 (D/S Deloro)	Moira HWY-7	Young's Creek
COBALT, UNFILTERED TOTAL	1979	mg/L	0.0009	mg/L													
COBALT, UNFILTERED TOTAL	1985	mg/L	0.0009	mg/L													0.12
COBALT, UNFILTERED TOTAL	1986	mg/L	0.0009	mg/L													0.082
COBALT, UNFILTERED TOTAL	1988	mg/L	0.0009	mg/L										0.0029	0.0052		
COBALT, UNFILTERED TOTAL	1989	mg/L	0.0009	mg/L										0.0014	0.0048		
COBALT, UNFILTERED TOTAL	1990	mg/L	0.0009	mg/L										0.0018	0.0045		
COBALT, UNFILTERED TOTAL	1991	mg/L	0.0009	mg/L										0.0009	0.0059		
COBALT, UNFILTERED TOTAL	1992	mg/L	0.0009	mg/L										0.0005	0.0025		
COBALT, UNFILTERED TOTAL	1993	mg/L	0.0009	mg/L										0.0005	0.0018	0.018	0.04
COBALT, UNFILTERED TOTAL	1994	mg/L	0.0009	mg/L		0.00025		0.0002	0.0002	0.0002	0.0002			0.0002	0.00139	0.010	0.18
COBALT, UNFILTERED TOTAL	1995	mg/L	0.0009	mg/L		0.00022		0.00024	0.00028	0.0005	0.00028			0.00035	0.00118	0.003	0.007
COBALT, UNFILTERED TOTAL	1996	mg/L	0.0009	mg/L		0.0004		0.0004	0.0003	0.0005	0.0003			0.0002	0.0016	0.003	0.10
COBALT, UNFILTERED TOTAL	1997	mg/L	0.0009	mg/L		0.0002		0.0004	0.0003	0.0004	0.0007				0.00121	0.03	0.14
COBALT, UNFILTERED TOTAL	1998	mg/L	0.0009	mg/L		0.0004		0.0005	0.0006	0.0004	0.0003	0.0008	0.0001		0.0023		
COBALT, UNFILTERED TOTAL	1999	mg/L	0.0009	mg/L		0.0002		0.0003	0.0002		0.0002	0.0004	0.0003	0.0004	0.0018		

PDESC	Year	UNITS	OWQO	Units	Moira D/S Young's Creek	HWY 62 Bridge	Moira Lk Narrows	Moira Lk Outlet	Stoco Lk Inlet	Beach at Tweed	Stoco Lk Outlet	Chapmans BRG	Stoco BRG	Cannifton	Belleville CNR BRG	Belleville HWY-2	Belleville Victoria St
COBALT, UNFILTERED TOTAL	1979	mg/L	0.0009	mg/L												0.02	
COBALT, UNFILTERED TOTAL	1985	mg/L	0.0009	mg/L													
COBALT, UNFILTERED TOTAL	1986	mg/L	0.0009	mg/L													
COBALT, UNFILTERED TOTAL	1988	mg/L	0.0009	mg/L		0.0028											
COBALT, UNFILTERED TOTAL	1989	mg/L	0.0009	mg/L		0.00305											
COBALT, UNFILTERED TOTAL	1990	mg/L	0.0009	mg/L		0.0026											
COBALT, UNFILTERED TOTAL	1991	mg/L	0.0009	mg/L		0.002											
COBALT, UNFILTERED TOTAL	1992	mg/L	0.0009	mg/L		0.0015											
COBALT, UNFILTERED TOTAL	1993	mg/L	0.0009	mg/L	0.0037	0.0012											0.0005
COBALT, UNFILTERED TOTAL	1994	mg/L	0.0009	mg/L	0.02	0.00147			0.00025		0.00035		0.00025	0.0002		0.00035	0.0005
COBALT, UNFILTERED TOTAL	1995	mg/L	0.0009	mg/L	0.004	0.0017			0.0007		0.00074		0.00054	0.00112		0.00054	0.0002
COBALT, UNFILTERED TOTAL	1996	mg/L	0.0009	mg/L	0.01	0.0024	0.0018		0.0008		0.0004		0.0007	0.0008		0.0007	
COBALT, UNFILTERED TOTAL	1997	mg/L	0.0009	mg/L	0.09		0.000913		0.0007		0.0003		0.0006	0.0002		0.0008	0.0002
COBALT, UNFILTERED TOTAL	1998	mg/L	0.0009	mg/L			0.0017		0.0008		0.0004		0.0007	0.0004		0.0004	0.0002
COBALT, UNFILTERED TOTAL	1999	mg/L	0.0009	mg/L			0.0013	0.0012	0.0006		0.0005		0.0003	0.0004		0.0005	0.0003

PDESC	Year	UNITS	OWQO	Units	Lily Cr	Deer Cr	Madoc Cr	Black R	Skootamatta R	Sulphide Cr	Clare R	Palliser Cr Quinte	Palliser Cr Foxborough	Malone	Moira HWY-7 (D/S Deloro)	Moira HWY-7	Young's Creek
COPPER, UNFILTERED TOTAL	1972	mg/L	0.005	mg/L*													
COPPER, UNFILTERED TOTAL	1973	mg/L	0.005	mg/L*													
COPPER, UNFILTERED TOTAL	1974	mg/L	0.005	mg/L*													
COPPER, UNFILTERED TOTAL	1975	mg/L	0.005	mg/L*													
COPPER, UNFILTERED TOTAL	1976	mg/L	0.005	mg/L*													
COPPER, UNFILTERED TOTAL	1977	mg/L	0.005	mg/L*													
COPPER, UNFILTERED TOTAL	1978	mg/L	0.005	mg/L*													
COPPER, UNFILTERED TOTAL	1979	mg/L	0.005	mg/L*													
COPPER, UNFILTERED TOTAL	1980	mg/L	0.005	mg/L*					0.019		0.0091						
COPPER, UNFILTERED TOTAL	1981	mg/L	0.005	mg/L*					0.026		0.0092						
COPPER, UNFILTERED TOTAL	1982	mg/L	0.005	mg/L*					0.033		0.015				0.016		
COPPER, UNFILTERED TOTAL	1983	mg/L	0.005	mg/L*					0.00775		0.011						
COPPER, UNFILTERED TOTAL	1984	mg/L	0.005	mg/L*		0.007			0.019		0.013						
COPPER, UNFILTERED TOTAL	1985	mg/L	0.005	mg/L*					0.006		0.015						0.028
COPPER, UNFILTERED TOTAL	1986	mg/L	0.005	mg/L*					0.015		0.013						0.042
COPPER, UNFILTERED TOTAL	1987	mg/L	0.005	mg/L*					0.015		0.002						
COPPER, UNFILTERED TOTAL	1988	mg/L	0.005	mg/L*					0.0073		0.0016			0.0032	0.0028		
COPPER, UNFILTERED TOTAL	1989	mg/L	0.005	mg/L*							0.0015			0.0020	0.0018		
COPPER, UNFILTERED TOTAL	1990	mg/L	0.005	mg/L*							0.0013			0.0013	0.0020		
COPPER, UNFILTERED TOTAL	1991	mg/L	0.005	mg/L*							0.00075			0.0008	0.0029		
COPPER, UNFILTERED TOTAL	1992	mg/L	0.005	mg/L*		0.0012		0.0013	0.0009	0.0009	0.00065			0.0012	0.0015		
COPPER, UNFILTERED TOTAL	1993	mg/L	0.005	mg/L*		0.00097		0.00092	0.0007	0.0006	0.00073			0.0007	0.0015	0.0027	0.009
COPPER, UNFILTERED TOTAL	1994	mg/L	0.005	mg/L*		0.0013		0.0012	0.0012	0.0012	0.0014			0.0012	0.0017	0.004	0.00525
COPPER, UNFILTERED TOTAL	1995	mg/L	0.005	mg/L*		0.0015		0.0012	0.0014	0.0012	0.0012			0.0023	0.002	0.002	0.002
COPPER, UNFILTERED TOTAL	1996	mg/L	0.005	mg/L*		0.0016		0.003	0.0023	0.0011	0.0004			0.0016	0.0018	0.00925	0.023
COPPER, UNFILTERED TOTAL	1997	mg/L	0.005	mg/L*		0.0005		0.0006	0.00058	0.0008	0.0008				0.0010	0.0165	0.01
COPPER, UNFILTERED TOTAL	1998	mg/L	0.005	mg/L*		0.0004		0.0002	0.0004	0.0006	0.0005	0.0005	0.0003		0.0006		
COPPER, UNFILTERED TOTAL	1999	mg/L	0.005	mg/L*		0.0009		0.0006	0.0006		0.0007	0.0003	0.0008	0.00022	0.0030		

PDESC	Year	UNITS	OWQO	Units	Moira D/S Young's Creek	HWY 62 Bridge	Moira Lk Narrows	Moira Lk Outlet	Stoco Lk Inlet	Beach at Tweed	Stoco Lk Outlet	Chapmans BRG	Stoco BRG	Cannifton	Belleville CNR BRG	Belleville HWY-2	Belleville Victoria St
COPPER, UNFILTERED TOTAL	1972	mg/L	0.005	mg/L*										**0.04**			
COPPER, UNFILTERED TOTAL	1973	mg/L	0.005	mg/L*										**0.059**			
COPPER, UNFILTERED TOTAL	1974	mg/L	0.005	mg/L*										**0.063**			
COPPER, UNFILTERED TOTAL	1975	mg/L	0.005	mg/L*										**0.042**			
COPPER, UNFILTERED TOTAL	1976	mg/L	0.005	mg/L*										**0.025**		**0.02**	
COPPER, UNFILTERED TOTAL	1977	mg/L	0.005	mg/L*												**0.03**	
COPPER, UNFILTERED TOTAL	1978	mg/L	0.005	mg/L*												**0.01**	
COPPER, UNFILTERED TOTAL	1979	mg/L	0.005	mg/L*												**0.011**	
COPPER, UNFILTERED TOTAL	1980	mg/L	0.005	mg/L*												**0.0081**	
COPPER, UNFILTERED TOTAL	1981	mg/L	0.005	mg/L*		**0.0079**										**0.0050**	
COPPER, UNFILTERED TOTAL	1982	mg/L	0.005	mg/L*		**0.0084**								**0.0091**		**0.0097**	
COPPER, UNFILTERED TOTAL	1983	mg/L	0.005	mg/L*		**0.0075**								**0.011**		**0.00825**	
COPPER, UNFILTERED TOTAL	1984	mg/L	0.005	mg/L*		**0.0091**								**0.011**		0.005	
COPPER, UNFILTERED TOTAL	1985	mg/L	0.005	mg/L*		0.005								**0.0062**		0.0046	
COPPER, UNFILTERED TOTAL	1986	mg/L	0.005	mg/L*		**0.0067**								0.005		0.002	
COPPER, UNFILTERED TOTAL	1987	mg/L	0.005	mg/L*		0.002								0.002		0.002	
COPPER, UNFILTERED TOTAL	1988	mg/L	0.005	mg/L*		0.0019								0.0016		0.0017	
COPPER, UNFILTERED TOTAL	1989	mg/L	0.005	mg/L*		0.0019							0.0011	0.0012		0.0012	
COPPER, UNFILTERED TOTAL	1990	mg/L	0.005	mg/L*		0.0018								0.0014		0.0012	
COPPER, UNFILTERED TOTAL	1991	mg/L	0.005	mg/L*		0.0012								0.0016		0.0011	
COPPER, UNFILTERED TOTAL	1992	mg/L	0.005	mg/L*		0.0013			**0.0063**		0.001		0.0009	0.0009		0.0010	
COPPER, UNFILTERED TOTAL	1993	mg/L	0.005	mg/L*	0.003	0.0013			0.00078		0.00075		0.00091	0.0006		0.0010	0.001
COPPER, UNFILTERED TOTAL	1994	mg/L	0.005	mg/L*	0.0028	0.0016			0.0015		0.0014		0.0012	0.0024		0.002	0.0011
COPPER, UNFILTERED TOTAL	1995	mg/L	0.005	mg/L*	0.0015	0.0035			0.0011		0.0019		0.0015	0.0027		0.0011	0.0033
COPPER, UNFILTERED TOTAL	1996	mg/L	0.005	mg/L*	0.0048	0.0016	0.0018		0.0019		0.0014		0.0009	0.0016		0.0015	
COPPER, UNFILTERED TOTAL	1997	mg/L	0.005	mg/L*	**0.011**		0.0012		0.0010		0.0008		0.0008	0.0006		0.0006	0.0005
COPPER, UNFILTERED TOTAL	1998	mg/L	0.005	mg/L*			0.0007		0.0007		0.0010		0.0006	0.0006		0.0004	0.0003
COPPER, UNFILTERED TOTAL	1999	mg/L	0.005	mg/L*			0.0007	0.0007	0.0006		0.0006		0.0007	0.0004		0.0006	0.0007

PDESC	Year	UNITS	OWQO	Units	Lily Cr	Deer Cr	Madoc Cr	Black R	Skootamatta R	Sulphide Cr	Clare R	Palliser Cr Quinte	Palliser Cr Foxborough	Malone	Moira HWY-7 (D/S Deloro)	Moira HWY-7	Young's Creek
LEAD, UNFILTERED TOTAL	1972	mg/L	0.005	mg/L-Interim													
LEAD, UNFILTERED TOTAL	1976	mg/L	0.005	mg/L-Interim													
LEAD, UNFILTERED TOTAL	1977	mg/L	0.005	mg/L-Interim													
LEAD, UNFILTERED TOTAL	1978	mg/L	0.005	mg/L-Interim													
LEAD, UNFILTERED TOTAL	1979	mg/L	0.005	mg/L-Interim													
LEAD, UNFILTERED TOTAL	1980	mg/L	0.005	mg/L-Interim					**0.015**		**0.022**						
LEAD, UNFILTERED TOTAL	1981	mg/L	0.005	mg/L-Interim					0.004		0.005						
LEAD, UNFILTERED TOTAL	1982	mg/L	0.005	mg/L-Interim					0.005		**0.005**				**0.0075**		
LEAD, UNFILTERED TOTAL	1983	mg/L	0.005	mg/L-Interim					**0.009**		0.0046						
LEAD, UNFILTERED TOTAL	1984	mg/L	0.005	mg/L-Interim		0.003			**0.006**		**0.056**						
LEAD, UNFILTERED TOTAL	1985	mg/L	0.005	mg/L-Interim					0.003		0.004						
LEAD, UNFILTERED TOTAL	1986	mg/L	0.005	mg/L-Interim					0.005		**0.013**						
LEAD, UNFILTERED TOTAL	1987	mg/L	0.005	mg/L-Interim					0.003		**0.011**						
LEAD, UNFILTERED TOTAL	1988	mg/L	0.005	mg/L-Interim					0.003		0.005			**0.0056**	0.005		
LEAD, UNFILTERED TOTAL	1989	mg/L	0.005	mg/L-Interim							0.005			0.005	0.005		
LEAD, UNFILTERED TOTAL	1990	mg/L	0.005	mg/L-Interim							0.005			0.005	0.005		
LEAD, UNFILTERED TOTAL	1991	mg/L	0.005	mg/L-Interim							0.0048			0.005	0.005		
LEAD, UNFILTERED TOTAL	1992	mg/L	0.005	mg/L-Interim		**0.0051**		**0.0052**	0.005	0.005	**0.0051**			0.005	0.005		
LEAD, UNFILTERED TOTAL	1993	mg/L	0.005	mg/L-Interim		0.005		0.005	0.005	0.005	0.005			0.005	0.005	**0.0066**	**0.051**
LEAD, UNFILTERED TOTAL	1994	mg/L	0.005	mg/L-Interim		**0.0052**		0.005	0.005	0.005	0.005			0.005	0.005	**0.012**	**0.0074**
LEAD, UNFILTERED TOTAL	1995	mg/L	0.005	mg/L-Interim		0.005		0.005	0.005	0.005	0.005			0.005	0.005	0.003	0.004
LEAD, UNFILTERED TOTAL	1996	mg/L	0.005	mg/L-Interim		0.005		0.005	0.005	0.005	0.005			0.005	0.005	0.001	0.0015
LEAD, UNFILTERED TOTAL	1997	mg/L	0.005	mg/L-Interim		0.004		0.003	0.001	0.0033	0.003				0.004	0.005	0.0025
LEAD, UNFILTERED TOTAL	1998	mg/L	0.005	mg/L-Interim		0.004		0.002	0.003	0.003	0.005	0.004	0.000		0.002		
LEAD, UNFILTERED TOTAL	1999	mg/L	0.005	mg/L-Interim		0.002		0.002	0.003		0.002	**0.005**	0.002	0.003	0.003		

PDESC	Year	UNITS	OWQO	Units	Moira D/S Young's Creek	HWY 62 Bridge	Moira Lk Narrows	Moira Lk Outlet	Stoco Lk Inlet	Beach at Tweed	Stoco Lk Outlet	Chapmans BRG	Stoco BRG	Cannifton	Belleville CNR BRG	Belleville HWY-2	Belleville Victoria St
LEAD, UNFILTERED TOTAL	1972	mg/L	0.005	mg/L-Interim										**0.01**			
LEAD, UNFILTERED TOTAL	1976	mg/L	0.005	mg/L-Interim												**0.01**	
LEAD, UNFILTERED TOTAL	1977	mg/L	0.005	mg/L-Interim												**0.02**	
LEAD, UNFILTERED TOTAL	1978	mg/L	0.005	mg/L-Interim												**0.03**	
LEAD, UNFILTERED TOTAL	1979	mg/L	0.005	mg/L-Interim												**0.031**	
LEAD, UNFILTERED TOTAL	1980	mg/L	0.005	mg/L-Interim												**0.016**	
LEAD, UNFILTERED TOTAL	1981	mg/L	0.005	mg/L-Interim		0.004										0.003	
LEAD, UNFILTERED TOTAL	1982	mg/L	0.005	mg/L-Interim		0.0038								0.004		0.003	
LEAD, UNFILTERED TOTAL	1983	mg/L	0.005	mg/L-Interim		0.003								**0.0052**		**0.0057**	
LEAD, UNFILTERED TOTAL	1984	mg/L	0.005	mg/L-Interim		**0.0055**								**0.0058**		0.003	
LEAD, UNFILTERED TOTAL	1985	mg/L	0.005	mg/L-Interim		0.003								0.0033		0.0031	
LEAD, UNFILTERED TOTAL	1986	mg/L	0.005	mg/L-Interim		0.003								0.0035		**0.020**	
LEAD, UNFILTERED TOTAL	1987	mg/L	0.005	mg/L-Interim		0.003								0.003		0.003	
LEAD, UNFILTERED TOTAL	1988	mg/L	0.005	mg/L-Interim		0.004								0.004		0.005	
LEAD, UNFILTERED TOTAL	1989	mg/L	0.005	mg/L-Interim		0.005							0.005	0.005		0.005	
LEAD, UNFILTERED TOTAL	1990	mg/L	0.005	mg/L-Interim		**0.0054**								0.005		0.005	
LEAD, UNFILTERED TOTAL	1991	mg/L	0.005	mg/L-Interim		0.005								0.005		0.005	
LEAD, UNFILTERED TOTAL	1992	mg/L	0.005	mg/L-Interim		0.005			0.005		0.005		0.005	0.005		0.005	
LEAD, UNFILTERED TOTAL	1993	mg/L	0.005	mg/L-Interim	0.0046	0.005			0.005		0.005		0.005	0.005		0.005	0.005
LEAD, UNFILTERED TOTAL	1994	mg/L	0.005	mg/L-Interim	**0.010**	**0.0051**			0.005		0.005		**0.0052**	**0.0051**		**0.0051**	0.005
LEAD, UNFILTERED TOTAL	1995	mg/L	0.005	mg/L-Interim	0.003	**0.00518**			0.005		0.005		0.005	**0.00516**		0.005	0.005
LEAD, UNFILTERED TOTAL	1996	mg/L	0.005	mg/L-Interim	0.001	0.005	0.005		0.005		0.005		0.005	0.005		0.005	
LEAD, UNFILTERED TOTAL	1997	mg/L	0.005	mg/L-Interim	0.004		0.003		0.0022		0.004		0.001	0.003		0.005	**0.0064**
LEAD, UNFILTERED TOTAL	1998	mg/L	0.005	mg/L-Interim			**0.0052**		0.004		0.0026		0.002	0.002		0.004	**0.0051**
LEAD, UNFILTERED TOTAL	1999	mg/L	0.005	mg/L-Interim			0.002	0.002	0.002		0.002		0.001	0.002		0.002	0.002

PDESC	Year	UNITS	OWQO	Units	Lily Cr	Deer Cr	Madoc Cr	Black R	Skootamatta R	Sulphide Cr	Clare R	Palliser Cr Quinte	Palliser Cr Foxborough	Malone	Moira HWY-7 (D/S Deloro)	Moira HWY-7	Young's Creek
NICKEL, UNFILTERED TOTAL	1972	mg/L	0.025	mg/L													
NICKEL, UNFILTERED TOTAL	1973	mg/L	0.025	mg/L													
NICKEL, UNFILTERED TOTAL	1974	mg/L	0.025	mg/L													
NICKEL, UNFILTERED TOTAL	1975	mg/L	0.025	mg/L													
NICKEL, UNFILTERED TOTAL	1976	mg/L	0.025	mg/L													
NICKEL, UNFILTERED TOTAL	1977	mg/L	0.025	mg/L													
NICKEL, UNFILTERED TOTAL	1978	mg/L	0.025	mg/L													
NICKEL, UNFILTERED TOTAL	1979	mg/L	0.025	mg/L													
NICKEL, UNFILTERED TOTAL	1982	mg/L	0.025	mg/L											0.008		
NICKEL, UNFILTERED TOTAL	1985	mg/L	0.025	mg/L													**0.059**
NICKEL, UNFILTERED TOTAL	1986	mg/L	0.025	mg/L													**0.046**
NICKEL, UNFILTERED TOTAL	1988	mg/L	0.025	mg/L					0.001		0.024			0.005	0.007		
NICKEL, UNFILTERED TOTAL	1989	mg/L	0.025	mg/L							0.002			0.002	0.0045		
NICKEL, UNFILTERED TOTAL	1990	mg/L	0.025	mg/L							0.0033			0.003	0.005		
NICKEL, UNFILTERED TOTAL	1991	mg/L	0.025	mg/L							0.0034			0.005	0.014		
NICKEL, UNFILTERED TOTAL	1992	mg/L	0.025	mg/L		0.0036		0.0021	0.002	0.003	0.0023			0.003	0.003		
NICKEL, UNFILTERED TOTAL	1993	mg/L	0.025	mg/L		0.0023		0.002	0.002	0.003	0.002			0.002	0.0025	0.006	0.025
NICKEL, UNFILTERED TOTAL	1994	mg/L	0.025	mg/L		0.002		0.002	0.002	0.003	0.002			0.0008	0.002	0.009	0.023
NICKEL, UNFILTERED TOTAL	1995	mg/L	0.025	mg/L		0.00052		0.00052	0.00054	0.003	0.0006			0.0006	0.001	0.008	0.020
NICKEL, UNFILTERED TOTAL	1996	mg/L	0.025	mg/L		0.0005		0.0005	0.002	0.003	0.0005			0.0005	0.0015	0.006	**0.042**
NICKEL, UNFILTERED TOTAL	1997	mg/L	0.025	mg/L		0.0001		0.001	0.0003	0.004	0.000				0.00072	0.0087	**0.057**
NICKEL, UNFILTERED TOTAL	1998	mg/L	0.025	mg/L		0.0004		0.0004	0.0004	0.002	0.001	0.001	0.001		0.002		
NICKEL, UNFILTERED TOTAL	1999	mg/L	0.025	mg/L		0.0005		0.0005	0.0004		0.001	0.0001	0.001	0.00087	0.003		
SILVER, UNFILTERED TOTAL	1987	mg/L	0.0001	mg/L													
URANIUM, UNFILTERED TOTAL	1991	mg/L	0.005	mg/L													

PDESC	Year	UNITS	OWQO	Units	Moira D/S Young's Creek	HWY 62 Bridge	Moira Lk Narrows	Moira Lk Outlet	Stoco Lk Inlet	Beach at Tweed	Stoco Lk Outlet	Chapmans BRG	Stoco BRG	Cannifton	Belleville CNR BRG	Belleville HWY-2	Belleville Victoria St
NICKEL, UNFILTERED TOTAL	1972	mg/L	0.025	mg/L										**0.044**			
NICKEL, UNFILTERED TOTAL	1973	mg/L	0.025	mg/L										**0.07**			
NICKEL, UNFILTERED TOTAL	1974	mg/L	0.025	mg/L										**0.072**			
NICKEL, UNFILTERED TOTAL	1975	mg/L	0.025	mg/L										**0.047**			
NICKEL, UNFILTERED TOTAL	1976	mg/L	0.025	mg/L										0.015		0.01	
NICKEL, UNFILTERED TOTAL	1977	mg/L	0.025	mg/L												0.012	
NICKEL, UNFILTERED TOTAL	1978	mg/L	0.025	mg/L												0.02	
NICKEL, UNFILTERED TOTAL	1979	mg/L	0.025	mg/L												0.02	
NICKEL, UNFILTERED TOTAL	1982	mg/L	0.025	mg/L													
NICKEL, UNFILTERED TOTAL	1985	mg/L	0.025	mg/L													
NICKEL, UNFILTERED TOTAL	1986	mg/L	0.025	mg/L													
NICKEL, UNFILTERED TOTAL	1988	mg/L	0.025	mg/L		0.0065								0.0022		0.0024	
NICKEL, UNFILTERED TOTAL	1989	mg/L	0.025	mg/L		0.0086							0.002	0.0023		0.0021	
NICKEL, UNFILTERED TOTAL	1990	mg/L	0.025	mg/L		0.0086								0.0038		0.0032	
NICKEL, UNFILTERED TOTAL	1991	mg/L	0.025	mg/L		0.0101								0.0039		0.0042	
NICKEL, UNFILTERED TOTAL	1992	mg/L	0.025	mg/L		0.0062			0.0035		0.0029		0.0026	0.0028		0.003	
NICKEL, UNFILTERED TOTAL	1993	mg/L	0.025	mg/L	0.0055	0.0055			0.002		0.002		0.002	0.002		0.0023	0.002
NICKEL, UNFILTERED TOTAL	1994	mg/L	0.025	mg/L	0.0049	0.0055			0.0020		0.0018		0.0018	0.0020		0.0019	0.0018
NICKEL, UNFILTERED TOTAL	1995	mg/L	0.025	mg/L	0.0039	0.0043			0.0021		0.0019		0.0019	0.0021		0.0016	0.0006
NICKEL, UNFILTERED TOTAL	1996	mg/L	0.025	mg/L	0.005	0.003	0.002		0.0022		0.0008		0.0008	0.0012		0.0015	
NICKEL, UNFILTERED TOTAL	1997	mg/L	0.025	mg/L	0.0233		0.0026		0.0017		0.0009		0.0019	0.0014		0.0014	0.0003
NICKEL, UNFILTERED TOTAL	1998	mg/L	0.025	mg/L		0.0081	0.0071		0.0021		0.0051		0.0015	0.0007		0.0009	0.0008
NICKEL, UNFILTERED TOTAL	1999	mg/L	0.025	mg/L			0.0050	0.0037	0.0018		0.0026		0.0018	0.0010		0.0010	0.0003
SILVER, UNFILTERED TOTAL	1987	mg/L	0.0001	mg/L												**0.0002**	
URANIUM, UNFILTERED TOTAL	1991	mg/L	0.005	mg/L		0.00024											

Note: Bold values indicate an exceedance of Ontario Water Quality Objectives (OWQO)
Annual averages include results found at limit of detection

Appendix I.6 Seasonal Concentrations of Metals of Concern

Mean Monthly Arsenic Concentration per Year for Station W2 [mg/L]

75%	Bold Values Represents Months Which are Above the Percentile Indicated												
PDESC	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ARSENIC, UNFILTERED TOTAL	1964											**0.32**	
ARSENIC, UNFILTERED TOTAL	1965			0.165	0.125	0.08	**0.3**	**1.25**	**3.667**	**4.167**	**0.25**		
ARSENIC, UNFILTERED TOTAL	1966								**2.5**				
ARSENIC, UNFILTERED TOTAL	1967										0.005	**0.224**	
ARSENIC, UNFILTERED TOTAL	1968				0.04	0.09	**0.49**	0.06	**0.54**	**0.88**		**0.29**	
ARSENIC, UNFILTERED TOTAL	1969		0.08	0.06	0.08		0.142	**0.18**	**1**	**1.52**	**0.47**	**0.56**	
ARSENIC, UNFILTERED TOTAL	1970				0.04	0.08	0.145	0.16	**0.455**	**0.925**	**0.35**	**0.275**	0.14
ARSENIC, UNFILTERED TOTAL	1971	0.1		**0.18**	0.05	0.055	0.04	**0.64**	**0.7**	**2.5**	**0.79**	**0.84**	
ARSENIC, UNFILTERED TOTAL	1972	0.1	0.06	0.055	0.03	0.1	0.04		**0.2**	0.02	0.085	0.03	0.03
ARSENIC, UNFILTERED TOTAL	1973	0.065	0.03	0.11	0.05	0.04	0.06	**0.195**	**0.58**	**0.48**	**0.5**	0.09	0.07
ARSENIC, UNFILTERED TOTAL	1974		0.04	0.02		0.06		**0.18**	**0.33**		0.02	0.02	
ARSENIC, UNFILTERED TOTAL	1975		0.095	0.01	0.01	0.035	0.13	**0.8**	**0.7**	**1.3**	**2.4**		0.1
ARSENIC, UNFILTERED TOTAL	1976	0.093		**0.17**	0.04	0.0435	0.03	0.001	0.13	**0.785**	**0.24**	0.13	0.059
ARSENIC, UNFILTERED TOTAL	1977	0.064	0.076	0.08	0.085	0.1	**0.45**	**0.585**		**5.75**	**0.174**	**0.41**	
ARSENIC, UNFILTERED TOTAL	1978		0.064		**0.215**	0.057	0.14	**0.445**	**1.3**	**1.32**	0.128	0.087	0.14
ARSENIC, UNFILTERED TOTAL	1979	**0.195**		**0.3**	0.058	0.04	0.03067	**0.331**	**0.77**	**0.73**	**1.35**	0.041	0.0525
ARSENIC, UNFILTERED TOTAL	1980	0.036	0.12	0.052	0.053	0.031	0.0615	0.1225	**0.345**	**1**	0.0915	0.018	0.028
ARSENIC, UNFILTERED TOTAL	1981	0.035	0.116	0.031	0.0285	0.0265	0.018	**0.2**	**0.815**	0.1	0.0925	0.0345	0.029
ARSENIC, UNFILTERED TOTAL	1982	0.042	0.05	0.0405	0.0475	0.0255	0.0565	**0.2**	**0.57**	**0.565**	**0.205**	0.034	0.0085
ARSENIC, UNFILTERED TOTAL	1983	0.016	0.015	0.0145	0.012	0.0195	0.0225	**0.269**	**0.624**	**0.737**	**0.301**	0.079	0.022
ARSENIC, UNFILTERED TOTAL	1984	0.015	0.02	0.012	0.006	0.0095	0.0595	0.0875	**0.285**	**0.21**	0.0655	0.0795	0.0205
ARSENIC, UNFILTERED TOTAL	1985	0.011		0.009	0.005	0.016	0.023	0.056	**0.24**	0.02	0.048	0.014	0.0175
ARSENIC, UNFILTERED TOTAL	1986	0.019	0.00833	0.0165	0.008	0.0085	0.007	0.052	0.014	0.021	0.0095	0.014	0.016
ARSENIC, UNFILTERED TOTAL	1987	0.008	0.017	0.016		0.029	0.021	0.046		**0.191**	0.129	0.016	0.0145
ARSENIC, UNFILTERED TOTAL	1988	0.018	0.014	0.013	0.011	0.019	0.0835	0.1285	0.007	**0.327**	**0.17**	0.015	
ARSENIC, UNFILTERED TOTAL	1989	0.023	0.024	0.039	0.006	0.0065	0.0105	0.029	0.0655	0.001	0.046	0.0215	
ARSENIC, UNFILTERED TOTAL	1990		0.006	0.0105	0.011	0.011	0.018	0.001	0.068	0.12	0.074	0.023	0.014
ARSENIC, UNFILTERED TOTAL	1991	0.0045	0.015	0.0075	0.0055	0.0055	0.012	0.1205	**0.25**	**0.315**	0.1325	0.1475	0.0365
ARSENIC, UNFILTERED TOTAL	1992	0.0235	0.018	0.012	0.0075	0.0155	0.11	0.1385	**0.18**	0.038	0.013	0.0105	0.011
ARSENIC, UNFILTERED TOTAL	1993	0.0095	0.009	0.0195	0.009	0.0195	0.01033	0.0305	0.074	0.092	0.039	0.019	0.006
ARSENIC, UNFILTERED TOTAL	1994	0.028	0.023	0.018	0.006	0.013	0.06	0.16	0.029			0.0188	0.009

75%
0.1675

75%	Bold Values Represents Months Which are Above the Percentile Indicated													
PDESC	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	75%
ARSENIC, UNFILTERED TOTAL	1995	0.015	0.023											
ARSENIC, UNFILTERED TOTAL	1999				0.012	0.03	0.032	0.16	0.13		**0.27**	0.018	0.014	
COBALT, UNFILTERED TOTAL	1988				**0.004**	0.0028	**0.004**	**0.005**	0.0025	**0.005**	**0.008**	**0.007**		0.00355
COBALT, UNFILTERED TOTAL	1989	**0.004**		0.0028	0.0024	0.0032	**0.004**	0.0031	**0.005**	**0.004**	**0.016**	**0.004**		
COBALT, UNFILTERED TOTAL	1990		**0.005**	0.0019	**0.008**	0.0019	0.0018	0.003	**0.004**	0.0035	**0.015**	0.003	0.0024	
COBALT, UNFILTERED TOTAL	1991	0.0014		0.0021	0.0016	0.0021	0.0015	**0.005**	0.0028	**0.004**	**0.013**	**0.014**	**0.019**	
COBALT, UNFILTERED TOTAL	1992	0.0031	0.003	**0.006**	0.001	0.001	0.003	0.0026	0.002	0.003	0.001	0.001		
COBALT, UNFILTERED TOTAL	1993	0.0015		**0.004**	0.0008	0.0011	0.00105	0.0014	0.0024	0.0024	0.0018	0.0016	0.0019	
COBALT, UNFILTERED TOTAL	1994	0.0007	0.0008	0.0015	0.0012	0.0013	0.0015	0.0023	0.0016			0.0002	0.0028	
COBALT, UNFILTERED TOTAL	1995	0.0008	0.0011	0.0006			0.001						0.0024	
COBALT, UNFILTERED TOTAL	1996	0.0016												
COBALT, UNFILTERED TOTAL	1997				0.00121									
COBALT, UNFILTERED TOTAL	1998				0.00163				0.00228		0.00212	0.00261	0.00272	
COBALT, UNFILTERED TOTAL	1999				0.001	0.00125	0.00156	0.00242	0.00184		0.00191	0.00255	0.00167	
COPPER, UNFILTERED TOTAL	1982	**0.003**									**0.029**			0.0024
COPPER, UNFILTERED TOTAL	1988				0.001	0.001	**0.003**	**0.007**	**0.004**	0.0024	0.0022	0.0023		
COPPER, UNFILTERED TOTAL	1989	0.0013		0.0015	0.0009	0.0015	0.0013	0.0021	**0.003**	**0.003**	0.0021	0.0013		
COPPER, UNFILTERED TOTAL	1990		0.0016	0.0012	**0.003**	0.001	0.002	0.002	**0.003**	**0.003**	**0.003**	0.002	0.001	
COPPER, UNFILTERED TOTAL	1991	0.001		0.001	0.002	0.001	0.0005	**0.003**	**0.003**	**0.003**	**0.003**	**0.013**	0.0015	
COPPER, UNFILTERED TOTAL	1992	0.001	**0.003**	0.002	0.001	0.001	0.001	0.002	0.0005	0.002	0.0005	0.002		
COPPER, UNFILTERED TOTAL	1993	0.0014		**0.003**	0.0007	0.0007	0.0013	0.0012	0.0021	0.0017	0.0012	0.0012	0.0021	
COPPER, UNFILTERED TOTAL	1994	0.0008	0.002	0.0024	0.0009	0.0022	0.0012	0.0019	**0.003**			0.0002	0.0022	
COPPER, UNFILTERED TOTAL	1995	**0.003**	0.0024	0.0017			0.001						0.0024	
COPPER, UNFILTERED TOTAL	1996	0.0018												
COPPER, UNFILTERED TOTAL	1997				0.00101									
COPPER, UNFILTERED TOTAL	1998				0.00075				0.00075		0.0013	0.00021	0.00036	
COPPER, UNFILTERED TOTAL	1999				0.00042	0.00062	0.00128	0.0024	**0.015**		0.00147	0.00093	0.00128	
LEAD, UNFILTERED TOTAL	1982	0.003									**0.012**			0.005
LEAD, UNFILTERED TOTAL	1988				0.003	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
LEAD, UNFILTERED TOTAL	1989	0.005		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
LEAD, UNFILTERED TOTAL	1990		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	
LEAD, UNFILTERED TOTAL	1991	0.005		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.003	
LEAD, UNFILTERED TOTAL	1992	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		

75%	Bold Values Represents Months Which are Above the Percentile Indicated													
PDESC	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	75%
LEAD, UNFILTERED TOTAL	1993	0.005		0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	
LEAD, UNFILTERED TOTAL	1994	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005			0.005	0.005	
LEAD, UNFILTERED TOTAL	1995	0.005	0.005	0.005			0.005						0.005	
LEAD, UNFILTERED TOTAL	1996	0.005												
LEAD, UNFILTERED TOTAL	1997				0.00418									
LEAD, UNFILTERED TOTAL	1998				0.00129				0.00394		0.00079	0.00196	0.00266	
LEAD, UNFILTERED TOTAL	1999				0.00246	0.00335	0.00027	0.00499	0.00076		0.00469	0.00348	0.00242	
NICKEL, UNFILTERED TOTAL	1982	0.003									**0.013**			0.006
NICKEL, UNFILTERED TOTAL	1988				0.003	0.002	0.006	**0.008**	**0.007**	**0.008**	**0.016**	**0.007**		
NICKEL, UNFILTERED TOTAL	1989	0.002		0.002	0.002	0.002	0.002	0.002	0.006	**0.009**	**0.014**	0.004		
NICKEL, UNFILTERED TOTAL	1990		0.004	0.002	0.006	0.004	0.004	0.005	**0.007**	**0.008**	**0.007**	**0.007**	0.002	
NICKEL, UNFILTERED TOTAL	1991	**0.012**		0.004	0.003	0.003	0.004	**0.009**	**0.012**	**0.012**	**0.017**	**0.065**	**0.01**	
NICKEL, UNFILTERED TOTAL	1992	0.006	0.005	**0.008**	0.002	0.002	0.003	0.003	0.003	0.002	0.002	0.002		
NICKEL, UNFILTERED TOTAL	1993	0.002		0.004	0.002	0.002	0.002	0.002	0.004	0.003	0.003	0.002	0.002	
NICKEL, UNFILTERED TOTAL	1994	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002			0.0005	0.0027	
NICKEL, UNFILTERED TOTAL	1995	0.0005	0.0012	0.0009			0.0012						0.0015	
NICKEL, UNFILTERED TOTAL	1996	0.0015												
NICKEL, UNFILTERED TOTAL	1997				0.00072									
NICKEL, UNFILTERED TOTAL	1998				0.00089				0.00323		0.00295	0.00126	0.00289	
NICKEL, UNFILTERED TOTAL	1999				0.00081	0.00194	0.00116	0.00429	**0.008**		0.00529	0.00246	0.00204	

APPENDIX II

SEDIMENT QUALITY METHODS AND DATA

Appendix II.1 MOE Laboratory Services Branch Method References for Sediment Analysis

MOE LABORATORY SERVICES BRANCH (LSB) METHOD REFERENCES FOR SEDIMENT ANALYSES

E3062
THE DETERMINATION OF HEAVY METALS IN SEDIMENTS BY THE SPECTRO INDUCTIVELY COUPLED PLASMA-OPTICAL EMISSION SPECTROMETER (ICP -OES)

E3215
THE DETERMINATION OF URANIUM IN SOIL AND SEDIMENTS BY INDUCTIVELY COUPLED PLASMA-MASS SPECTROSCOPY (ICP -MS)

E3245
THE DETERMINATION OF ARSENIC, SELENIUM AND ANTIMONY IN VEGETATION, COMPOST, SOIL AND SEDIMENTS BY HYDRIDE-FLAMELESS ATOMIC ABSORPTION SPECTROPHOTOMETRY (HYD-FAAS)

LSB METHOD DETECTION LIMITS

E3062

Element	Detection Limit	Units
Al	200	ug/g
Co	0.5	ug/g
Cu	1.0	ug/g
Ni	0.5	ug/g
Pb	2.0	ug/g
Zn	5.0	ug/g

E3215

Element	Detection Limit	Units
U	0.2	ug/g

E3245

Element	Detection Limit	Units
As	0.2	ug/g

PHILIP SERVICES LABORATORY METHODS

Metals, total – Samples were dried at approx. 38C, disaggrated and sieved using 60 mesh. The –60 mesh was collected and used for analysis.

Digestion: 1.0 g was digested with HCl/HNO_3 acids. The digestate was analysed for:

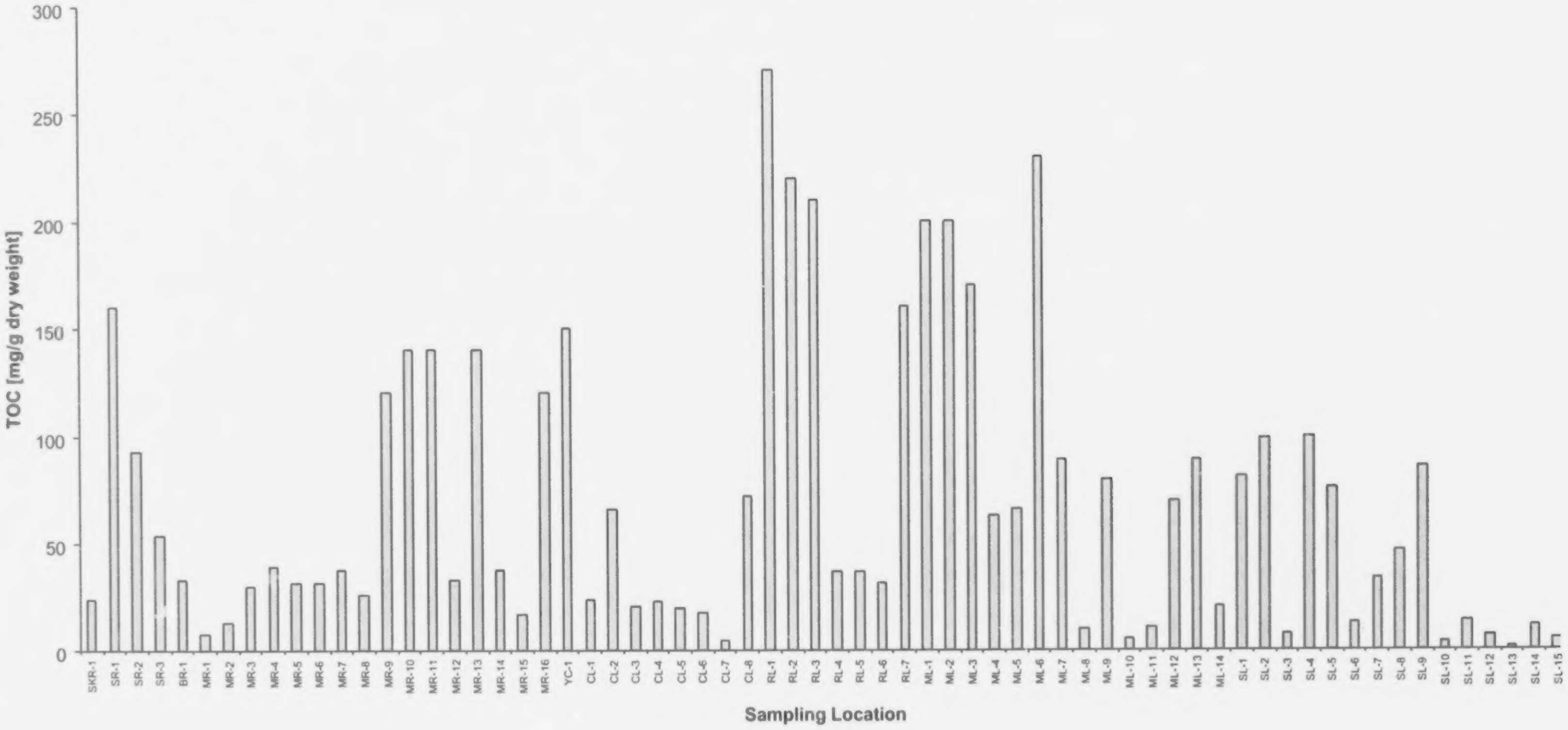
(a) As by Hydride Generation Atomic Absorption (SW 7061)
(b) Hg by Cold Vapor Atomic Absorption Spectrophotometer (SW 7470)
(c) U by ICP/MS (SW6020 mod.)
(d) Other Metals by ICAP (SW6010 mod.)

The following Sequential Extraction Procedure was used for the Speciation of Particulate Trace Metals:

(a) Fraction 1 – Exchangeable metals, extraction with 1M NaOAc, pH 8.2
(b) Fraction 2 – Bound to Carbonates, extraction with 1M NaOAc, pH 5.0
(c) Fraction 3 - Bound to Fe-Mn Oxides, extraction with $NH_2OH.HCl/HOAc$
(d) Fraction 4 – Bound to Organic Matter, extraction with $HNO_3/H_2O_2/NH_4Oac$
(e) Fraction 5 – Residual, residue was digested with $HF/HNO_3/HClO_4$ and the digestate was analysed by ICAP (SW 6010 mod).

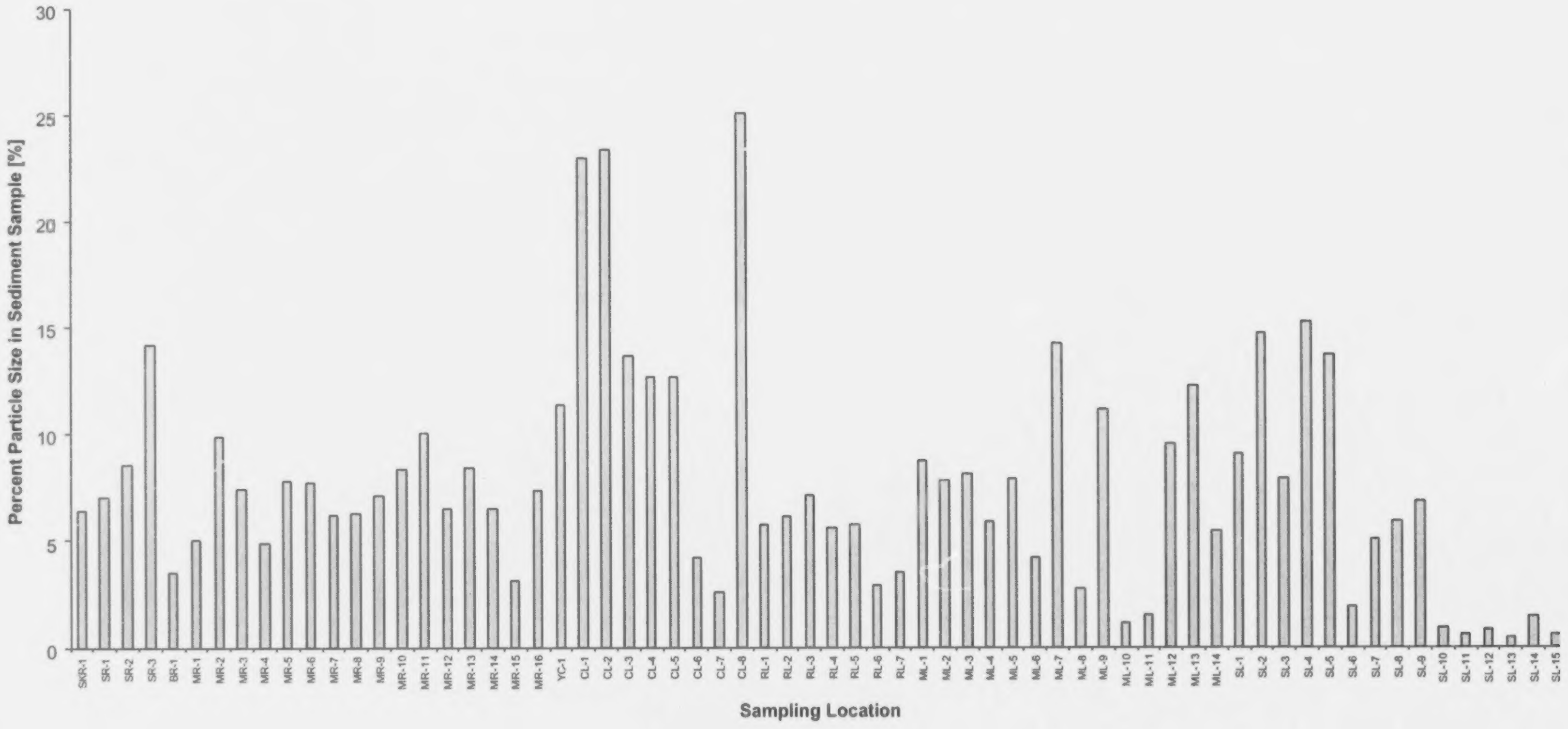
Appendix II.2 Total Organic Carbon Content and Particle Size of Sediments

Total Organic Content (TOC) in Sediment Grab Samples

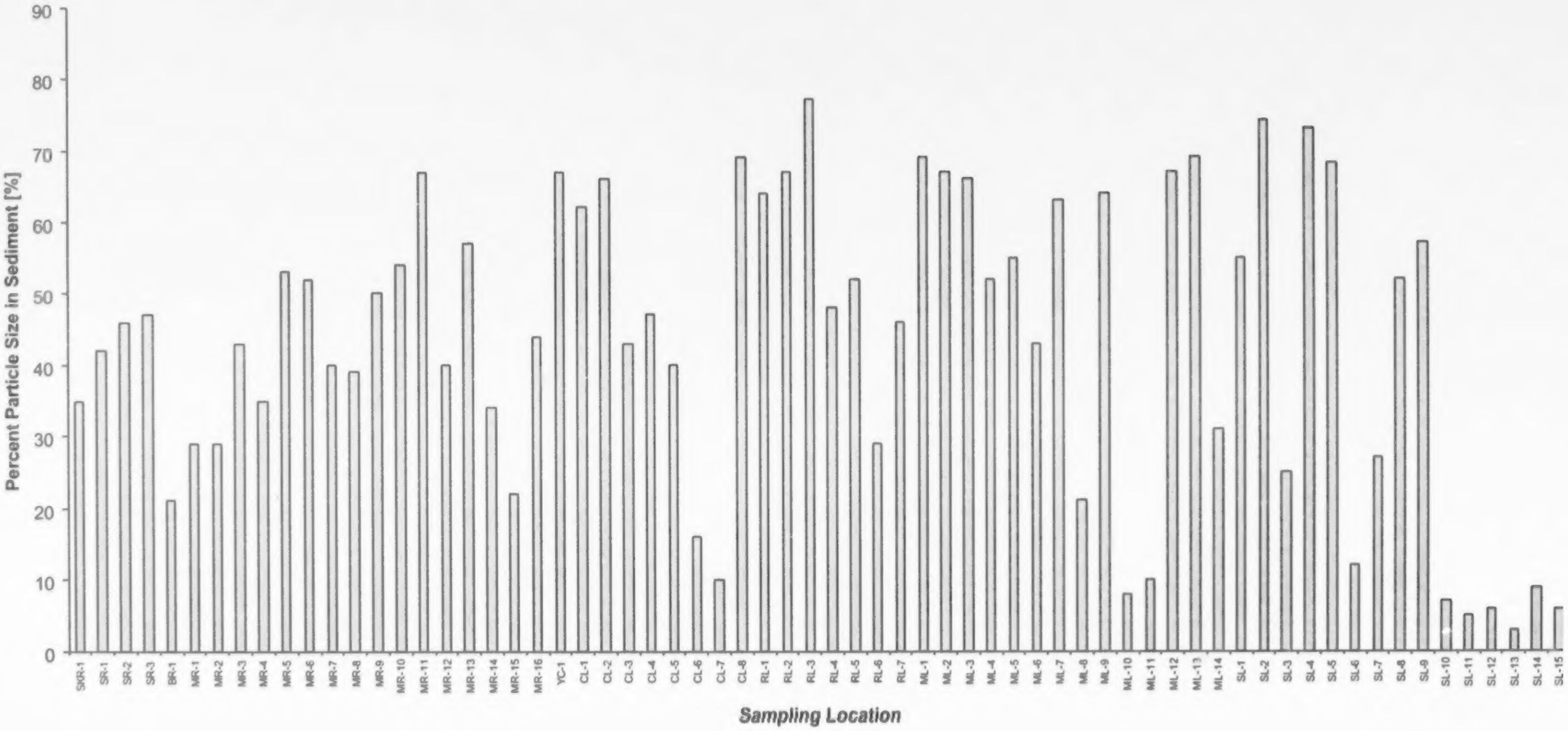


II.2-2

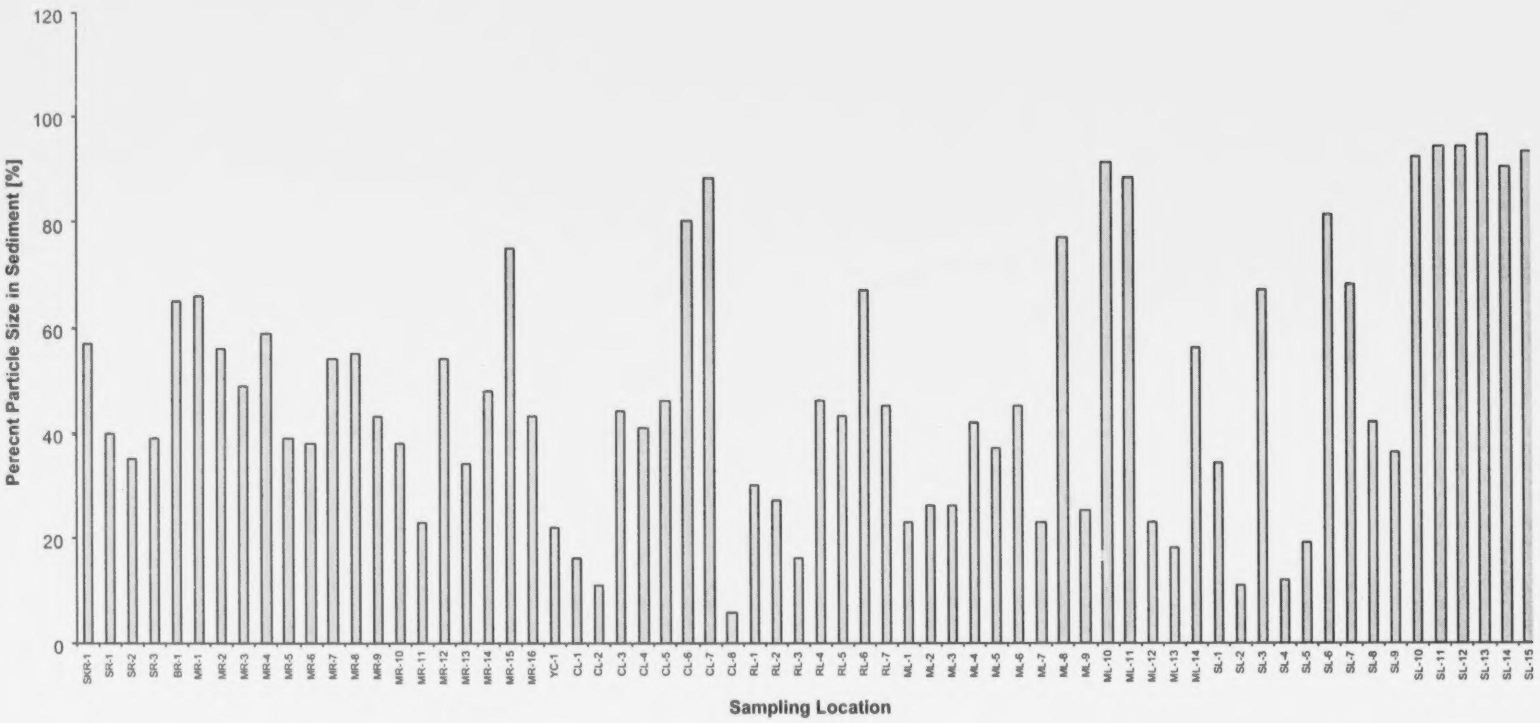
Percent Fine Sediments per Sampling Location (0.17 to 2.63 um)

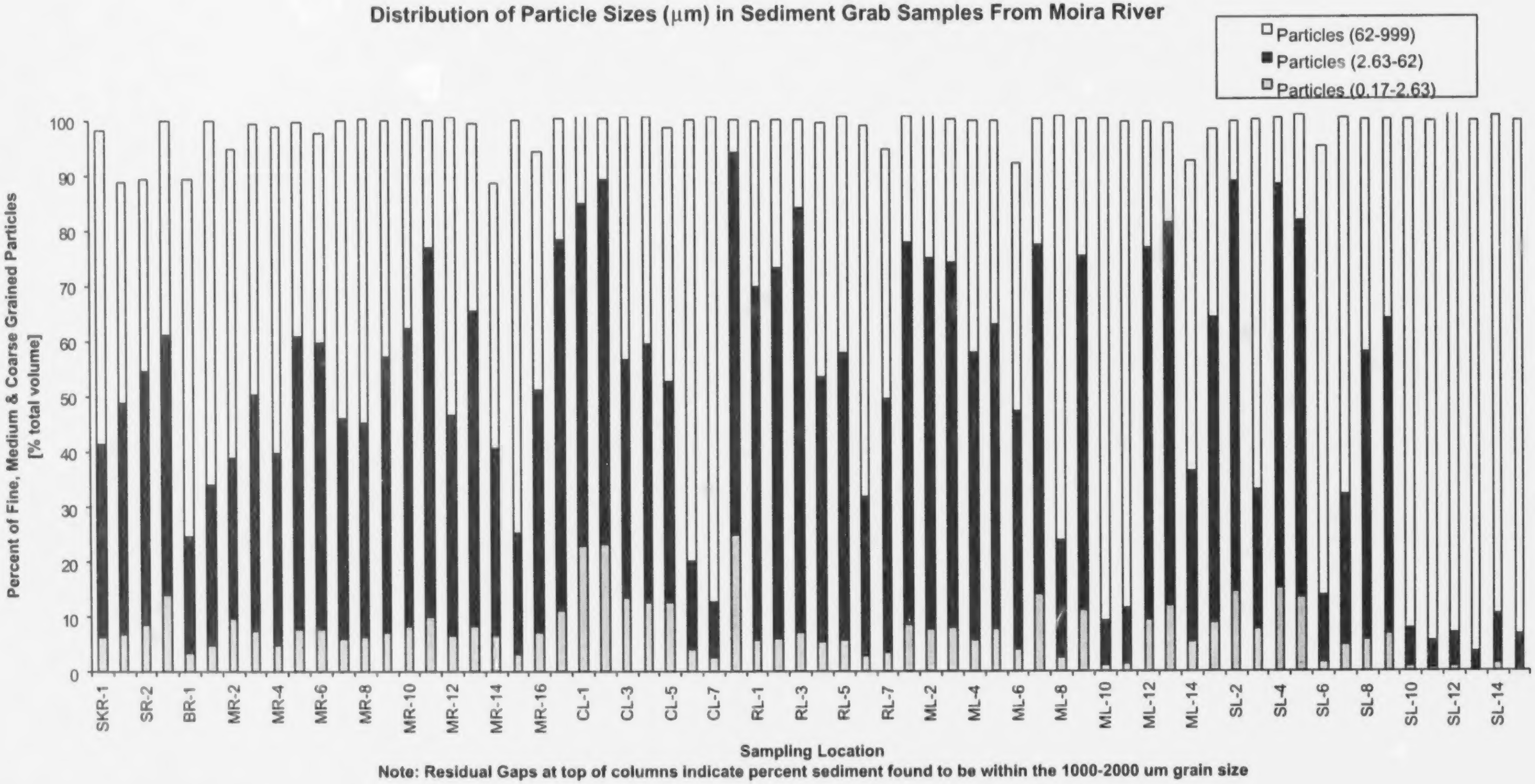


Percent Medium Grain Sediments per Sampling Location (2.63-62 ^{u}m)



Percent Coarse Grain Sediments per Sampling Location (62-999 um)



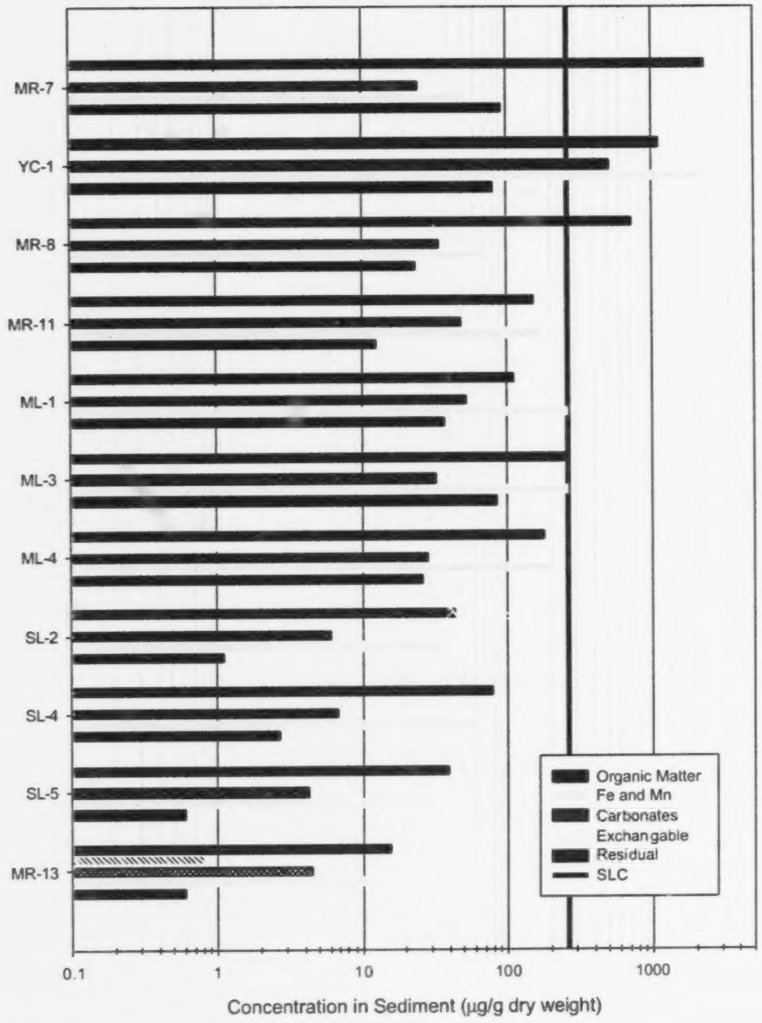


Distribution of Particle Sizes (μm) in Sediment Grab Samples From Moira River

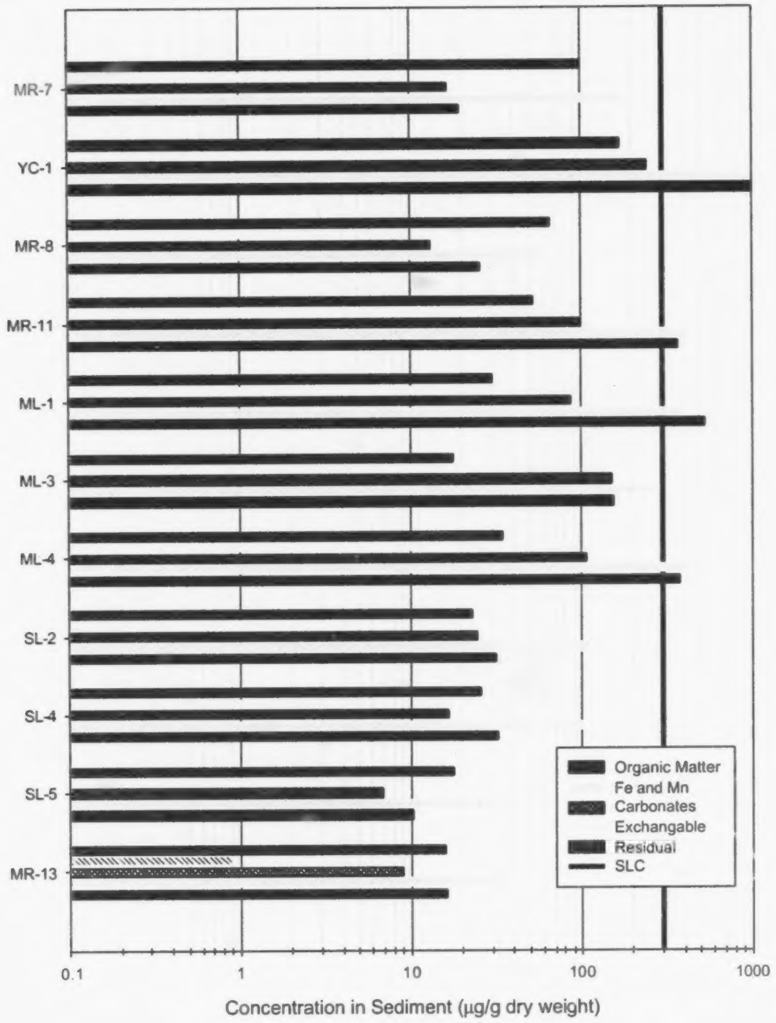
Note: Residual Gaps at top of columns indicate percent sediment found to be within the 1000-2000 um grain size

Appendix II.3 Concentrations of Metals of Concern in Chemical Fractions of the Top Five Centimetres of Sediment Cores

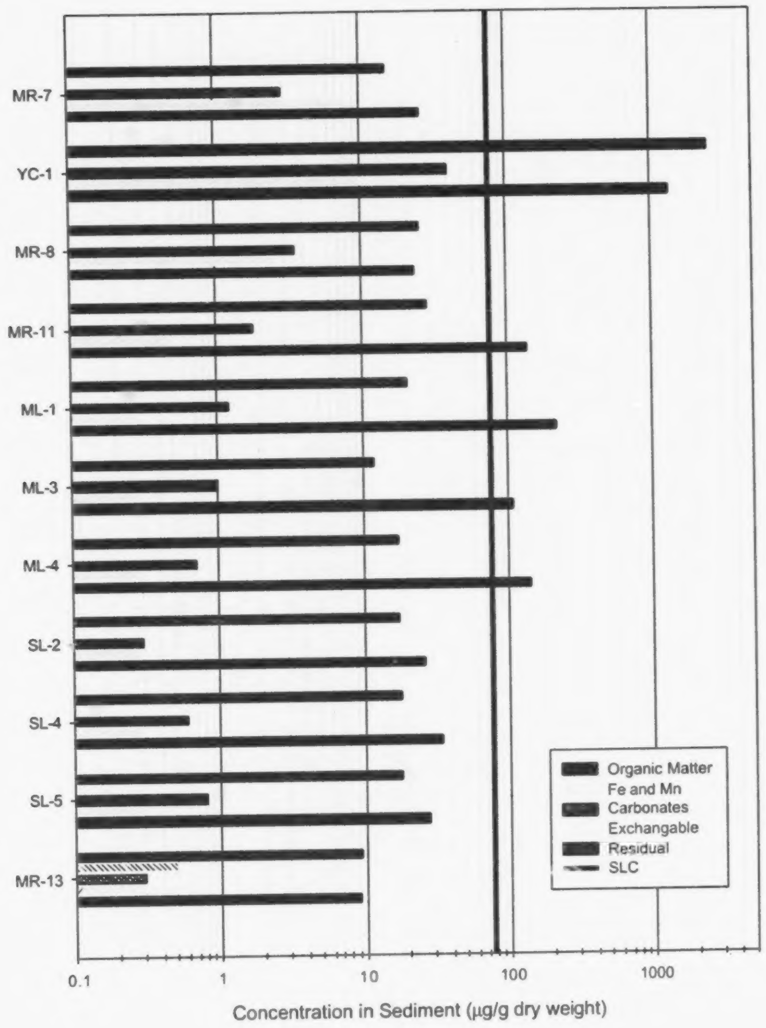
Concentration of Arsenic in Various Chemical Fractions in 0-5 cm Deep Sediment Cores – Moira River Watershed, 1999



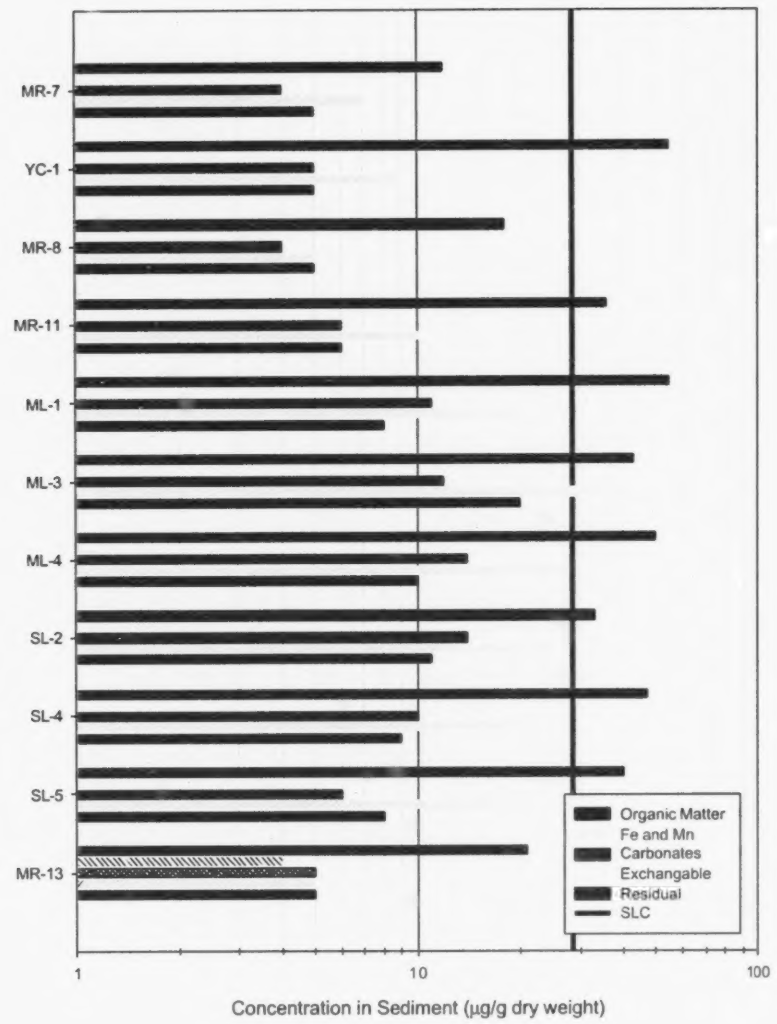
Concentration of Cobalt in Various Chemical Fractions in 0-5 cm Deep Sediment Cores – Moira River Watershed, 1999



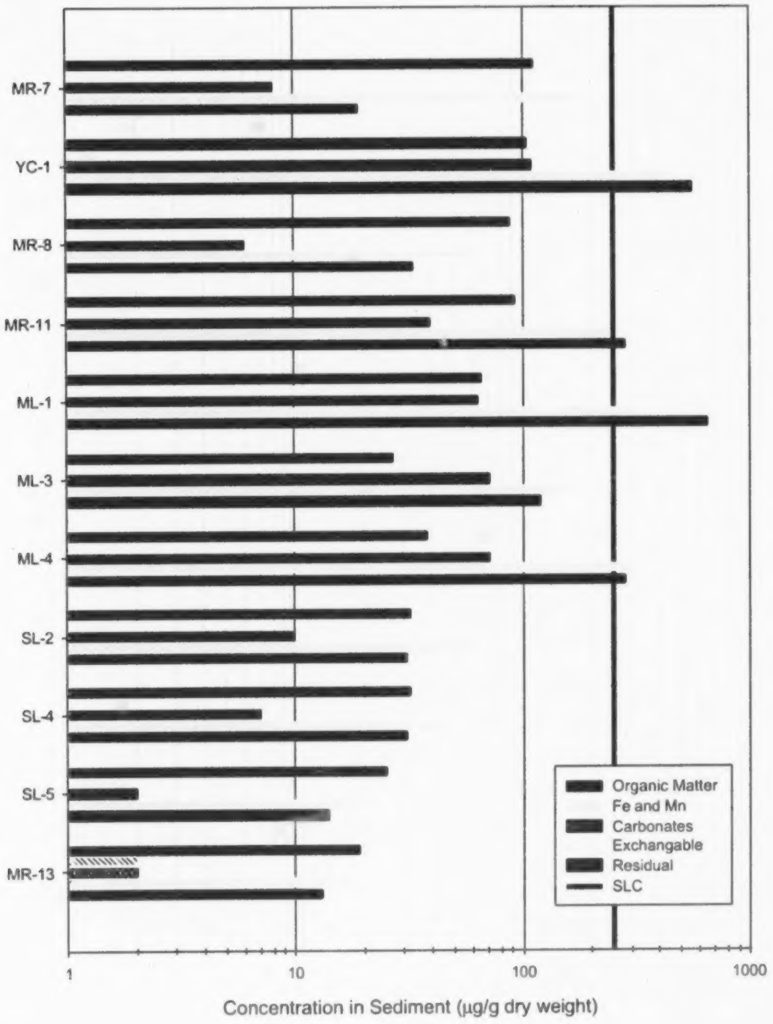
Concentration of Copper in Various Chemical Fractions in 0-5 cm Deep Sediment Cores – Moira River Watershed, 1999



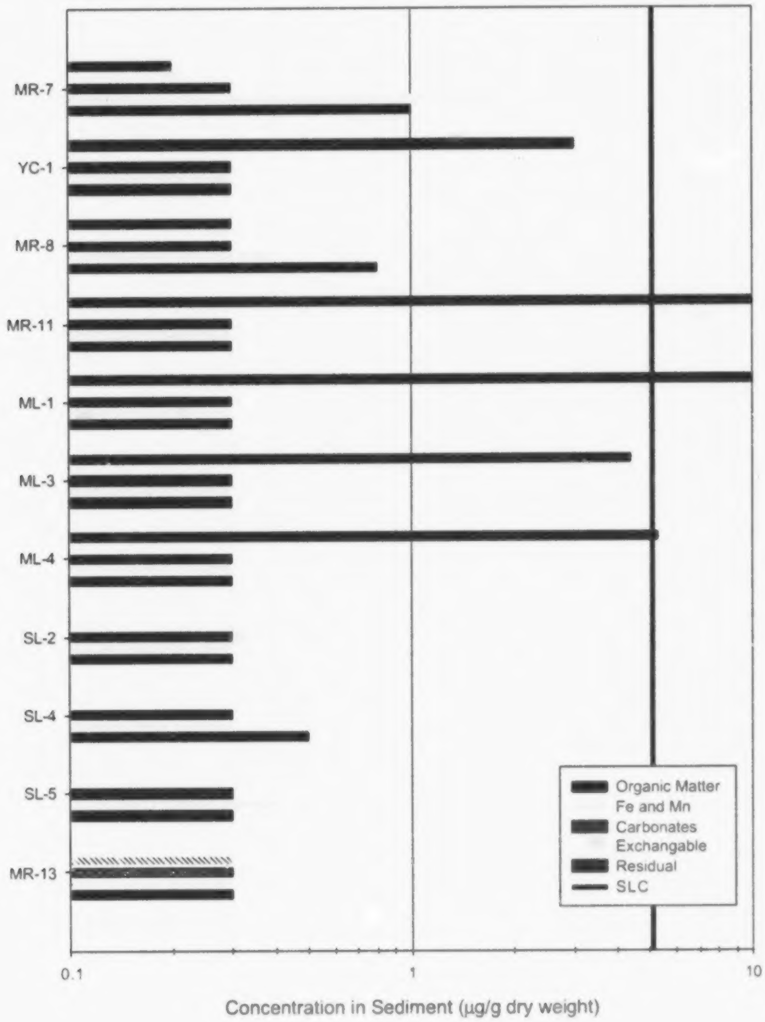
Concentration of Lead in Various Chemical Fractions in 0-5 cm Deep Sediment Cores – Moira River Watershed, 1999



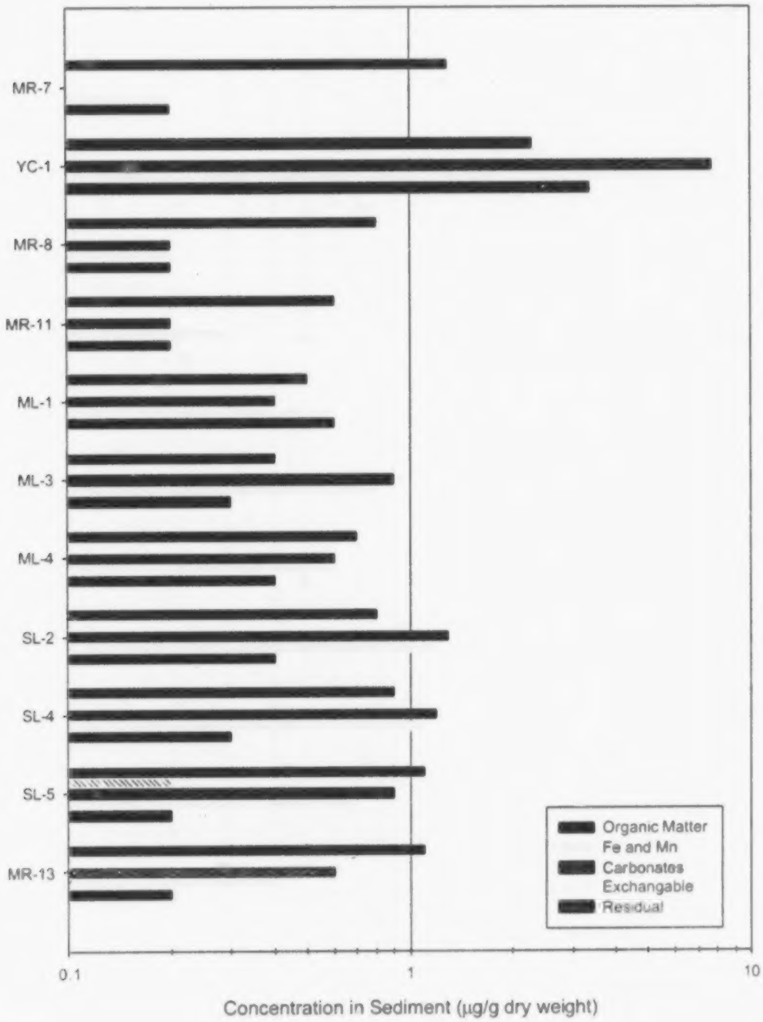
Concentration of Nickel in Various Chemical Fractions in 0-5 cm Deep Sediment Cores – Moira River Watershed, 1999



Concentration of Silver in Various Chemical Fractions in 0-5 cm Deep Sediment Cores – Moira River Watershed, 1999



Concentration of Uranium in Various Chemical Fractions in 0-5 cm Deep Sediment Cores – Moira River Watershed, 1999



Appendix II.4 Sediment Grab Data

Sediment Grab Data

Parameter	Golder Station	Result	Remark	Units	Date
Aluminum	BR-1	6100		ug/g dry	4/1/99
Aluminum	CL-1	600	<T	ug/g dry	4/1/99
Aluminum	CL-2	5500		ug/g dry	4/1/99
Aluminum	CL-3	4200		ug/g dry	4/1/99
Aluminum	CL-4	1700		ug/g dry	4/1/99
Aluminum	CL-5	800	<T	ug/g dry	4/1/99
Aluminum	CL-6	2600		ug/g dry	4/1/99
Aluminum	CL-7	2200		ug/g dry	4/1/99
Aluminum	CL-8	10000		ug/g dry	4/1/99
Aluminum	ML-1	12000		ug/g dry	4/1/99
Aluminum	ML-10	4600		ug/g dry	4/1/99
Aluminum	ML-11	3700		ug/g dry	4/1/99
Aluminum	ML-12	4800		ug/g dry	4/1/99
Aluminum	ML-13	2900		ug/g dry	4/1/99
Aluminum	ML-14	3100		ug/g dry	4/1/99
Aluminum	ML-2	16000		ug/g dry	4/1/99
Aluminum	ML-3	12000		ug/g dry	4/1/99
Aluminum	ML-4	6200		ug/g dry	4/1/99
Aluminum	ML-5	3800		ug/g dry	4/1/99
Aluminum	ML-6	3700		ug/g dry	4/1/99
Aluminum	ML-7	2200		ug/g dry	4/1/99
Aluminum	ML-8	4700		ug/g dry	4/1/99
Aluminum	ML-9	13000		ug/g dry	4/1/99
Aluminum	MR-1	7900		ug/g dry	4/1/99
Aluminum	MR-10	13000		ug/g dry	4/1/99
Aluminum	MR-11	18000		ug/g dry	4/1/99
Aluminum	MR-12	6900		ug/g dry	4/1/99
Aluminum	MR-13	18000		ug/g dry	4/1/99
Aluminum	MR-14	10000		ug/g dry	4/1/99
Aluminum	MR-15	5100		ug/g dry	4/1/99
Aluminum	MR-16	11000		ug/g dry	4/1/99
Aluminum	MR-2	15000		ug/g dry	4/1/99
Aluminum	MR-3	11000		ug/g dry	4/1/99
Aluminum	MR-4	13000		ug/g dry	4/1/99
Aluminum	MR-5	14000		ug/g dry	4/1/99
Aluminum	MR-6	12000		ug/g dry	4/1/99
Aluminum	MR-7	11000		ug/g dry	4/1/99
Aluminum	MR-8	10000		ug/g dry	4/1/99
Aluminum	MR-9	13000		ug/g dry	4/1/99
Aluminum	RL-1	10000		ug/g dry	4/1/99
Aluminum	RL-2	17000		ug/g dry	4/1/99
Aluminum	RL-3	20000		ug/g dry	4/1/99
Aluminum	RL-4	5800		ug/g dry	4/1/99
Aluminum	RL-5	6200		ug/g dry	4/1/99
Aluminum	RL-6	5500		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Aluminum	RL-7	7200		ug/g dry	4/1/99
Aluminum	SKR-1	7000		ug/g dry	4/1/99
Aluminum	SL-1	11000		ug/g dry	4/1/99
Aluminum	SL-10	3700		ug/g dry	4/1/99
Aluminum	SL-11	2900		ug/g dry	4/1/99
Aluminum	SL-12	2800		ug/g dry	4/1/99
Aluminum	SL-13	2400		ug/g dry	4/1/99
Aluminum	SL-14	3100		ug/g dry	4/1/99
Aluminum	SL-15	2800		ug/g dry	4/1/99
Aluminum	SL-2	22000		ug/g dry	4/1/99
Aluminum	SL-3	7700		ug/g dry	4/1/99
Aluminum	SL-4	21000		ug/g dry	4/1/99
Aluminum	SL-5	20000		ug/g dry	4/1/99
Aluminum	SL-6	5300		ug/g dry	4/1/99
Aluminum	SL-7	6800		ug/g dry	4/1/99
Aluminum	SL-8	7700		ug/g dry	4/1/99
Aluminum	SL-9	11000		ug/g dry	4/1/99
Aluminum	SR-1	14000		ug/g dry	4/1/99
Aluminum	SR-2	19000		ug/g dry	4/1/99
Aluminum	SR-3	23000		ug/g dry	4/1/99
Aluminum	YC-1	20000		ug/g dry	4/1/99
Arsenic	BR-1	4.7		ug/g dry	4/1/99
Arsenic	CL-1	0.8	<T	ug/g dry	4/1/99
Arsenic	CL-2	1.7		ug/g dry	4/1/99
Arsenic	CL-3	1.7		ug/g dry	4/1/99
Arsenic	CL-4	0.9	<T	ug/g dry	4/1/99
Arsenic	CL-5	0.6	<T	ug/g dry	4/1/99
Arsenic	CL-6	0.6	<T	ug/g dry	4/1/99
Arsenic	CL-7	0.6	<T	ug/g dry	4/1/99
Arsenic	CL-8	3.8		ug/g dry	4/1/99
Arsenic	ML-1	310		ug/g dry	4/1/99
Arsenic	ML-10	8.8		ug/g dry	4/1/99
Arsenic	ML-11	17		ug/g dry	4/1/99
Arsenic	ML-12	100		ug/g dry	4/1/99
Arsenic	ML-13	170		ug/g dry	4/1/99
Arsenic	ML-14	31		ug/g dry	4/1/99
Arsenic	ML-2	290		ug/g dry	4/1/99
Arsenic	ML-3	600		ug/g dry	4/1/99
Arsenic	ML-4	150		ug/g dry	4/1/99
Arsenic	ML-5	150		ug/g dry	4/1/99
Arsenic	ML-6	110		ug/g dry	4/1/99
Arsenic	ML-7	210		ug/g dry	4/1/99
Arsenic	ML-8	15		ug/g dry	4/1/99
Arsenic	ML-9	57		ug/g dry	4/1/99
Arsenic	MR-1	1.4		ug/g dry	4/1/99
Arsenic	MR-10	260		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Arsenic	MR-11	660		ug/g dry	4/1/99
Arsenic	MR-12	17		ug/g dry	4/1/99
Arsenic	MR-13	50		ug/g dry	4/1/99
Arsenic	MR-14	21		ug/g dry	4/1/99
Arsenic	MR-15	11		ug/g dry	4/1/99
Arsenic	MR-16	29		ug/g dry	4/1/99
Arsenic	MR-2	2.9		ug/g dry	4/1/99
Arsenic	MR-3	14		ug/g dry	4/1/99
Arsenic	MR-4	140		ug/g dry	4/1/99
Arsenic	MR-5	170		ug/g dry	4/1/99
Arsenic	MR-6	280		ug/g dry	4/1/99
Arsenic	MR-7	500		ug/g dry	4/1/99
Arsenic	MR-8	1300		ug/g dry	4/1/99
Arsenic	MR-9	260		ug/g dry	4/1/99
Arsenic	RL-1	5.7		ug/g dry	4/1/99
Arsenic	RL-2	4.3		ug/g dry	4/1/99
Arsenic	RL-3	5.5		ug/g dry	4/1/99
Arsenic	RL-4	1		ug/g dry	4/1/99
Arsenic	RL-5	1		ug/g dry	4/1/99
Arsenic	RL-6	0.8	<T	ug/g dry	4/1/99
Arsenic	RL-7	2.8		ug/g dry	4/1/99
Arsenic	SKR-1	2.3		ug/g dry	4/1/99
Arsenic	SL-1	42		ug/g dry	4/1/99
Arsenic	SL-10	6.2		ug/g dry	4/1/99
Arsenic	SL-11	7.5		ug/g dry	4/1/99
Arsenic	SL-12	4.6		ug/g dry	4/1/99
Arsenic	SL-13	2.9		ug/g dry	4/1/99
Arsenic	SL-14	2.6		ug/g dry	4/1/99
Arsenic	SL-15	3.9		ug/g dry	4/1/99
Arsenic	SL-2	99		ug/g dry	4/1/99
Arsenic	SL-3	96		ug/g dry	4/1/99
Arsenic	SL-4	130		ug/g dry	4/1/99
Arsenic	SL-5	54		ug/g dry	4/1/99
Arsenic	SL-6	6.3		ug/g dry	4/1/99
Arsenic	SL-7	12		ug/g dry	4/1/99
Arsenic	SL-8	16		ug/g dry	4/1/99
Arsenic	SL-9	36		ug/g dry	4/1/99
Arsenic	SR-1	2.4		ug/g dry	4/1/99
Arsenic	SR-2	2.1		ug/g dry	4/1/99
Arsenic	SR-3	2.1		ug/g dry	4/1/99
Arsenic	YC-1	3000		ug/g dry	4/1/99
Barium	BR-1	73		ug/g dry	4/1/99
Barium	CL-1	66		ug/g dry	4/1/99
Barium	CL-2	87		ug/g dry	4/1/99
Barium	CL-3	44		ug/g dry	4/1/99
Barium	CL-4	54		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Barium	CL-5	55		ug/g dry	4/1/99
Barium	CL-6	21		ug/g dry	4/1/99
Barium	CL-7	14		ug/g dry	4/1/99
Barium	CL-8	100		ug/g dry	4/1/99
Barium	ML-1	60		ug/g dry	4/1/99
Barium	ML-10	40		ug/g dry	4/1/99
Barium	ML-11	37		ug/g dry	4/1/99
Barium	ML-12	120		ug/g dry	4/1/99
Barium	ML-13	76		ug/g dry	4/1/99
Barium	ML-14	150		ug/g dry	4/1/99
Barium	ML-2	39		ug/g dry	4/1/99
Barium	ML-3	24		ug/g dry	4/1/99
Barium	ML-4	110		ug/g dry	4/1/99
Barium	ML-5	200		ug/g dry	4/1/99
Barium	ML-6	61		ug/g dry	4/1/99
Barium	ML-7	140		ug/g dry	4/1/99
Barium	ML-8	68		ug/g dry	4/1/99
Barium	ML-9	320		ug/g dry	4/1/99
Barium	MR-1	95		ug/g dry	4/1/99
Barium	MR-10	75		ug/g dry	4/1/99
Barium	MR-11	39		ug/g dry	4/1/99
Barium	MR-12	100		ug/g dry	4/1/99
Barium	MR-13	110		ug/g dry	4/1/99
Barium	MR-14	160		ug/g dry	4/1/99
Barium	MR-15	51		ug/g dry	4/1/99
Barium	MR-16	170		ug/g dry	4/1/99
Barium	MR-2	150		ug/g dry	4/1/99
Barium	MR-3	160		ug/g dry	4/1/99
Barium	MR-4	240		ug/g dry	4/1/99
Barium	MR-5	200		ug/g dry	4/1/99
Barium	MR-6	220		ug/g dry	4/1/99
Barium	MR-7	180		ug/g dry	4/1/99
Barium	MR-8	210		ug/g dry	4/1/99
Barium	MR-9	190		ug/g dry	4/1/99
Barium	RL-1	35		ug/g dry	4/1/99
Barium	RL-2	130		ug/g dry	4/1/99
Barium	RL-3	61		ug/g dry	4/1/99
Barium	RL-4	83		ug/g dry	4/1/99
Barium	RL-5	85		ug/g dry	4/1/99
Barium	RL-6	45		ug/g dry	4/1/99
Barium	RL-7	48		ug/g dry	4/1/99
Barium	SKR-1	77		ug/g dry	4/1/99
Barium	SL-1	140		ug/g dry	4/1/99
Barium	SL-10	26		ug/g dry	4/1/99
Barium	SL-11	22		ug/g dry	4/1/99
Barium	SL-12	21		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Barium	SL-13	19		ug/g dry	4/1/99
Barium	SL-14	21		ug/g dry	4/1/99
Barium	SL-15	23		ug/g dry	4/1/99
Barium	SL-2	260		ug/g dry	4/1/99
Barium	SL-3	100		ug/g dry	4/1/99
Barium	SL-4	230		ug/g dry	4/1/99
Barium	SL-5	270		ug/g dry	4/1/99
Barium	SL-6	83		ug/g dry	4/1/99
Barium	SL-7	100		ug/g dry	4/1/99
Barium	SL-8	99		ug/g dry	4/1/99
Barium	SL-9	160		ug/g dry	4/1/99
Barium	SR-1	180		ug/g dry	4/1/99
Barium	SR-2	160		ug/g dry	4/1/99
Barium	SR-3	210		ug/g dry	4/1/99
Barium	YC-1	50		ug/g dry	4/1/99
Beryllium	BR-1	0.5	<=W	ug/g dry	4/1/99
Beryllium	CL-1	0.5	<=W	ug/g dry	4/1/99
Beryllium	CL-2	0.5	<=W	ug/g dry	4/1/99
Beryllium	CL-3	0.5	<=W	ug/g dry	4/1/99
Beryllium	CL-4	0.5	<=W	ug/g dry	4/1/99
Beryllium	CL-5	0.5	<=W	ug/g dry	4/1/99
Beryllium	CL-6	0.5	<=W	ug/g dry	4/1/99
Beryllium	CL-7	0.5	<=W	ug/g dry	4/1/99
Beryllium	CL-8	0.5	<=W	ug/g dry	4/1/99
Beryllium	ML-1	0.6	<T	ug/g dry	4/1/99
Beryllium	ML-10	0.5	<=W	ug/g dry	4/1/99
Beryllium	ML-11	0.5	<=W	ug/g dry	4/1/99
Beryllium	ML-12	0.5	<=W	ug/g dry	4/1/99
Beryllium	ML-13	0.5	<=W	ug/g dry	4/1/99
Beryllium	ML-14	0.5	<=W	ug/g dry	4/1/99
Beryllium	ML-2	0.8	<T	ug/g dry	4/1/99
Beryllium	ML-3	0.7	<T	ug/g dry	4/1/99
Beryllium	ML-4	0.5	<=W	ug/g dry	4/1/99
Beryllium	ML-5	0.5	<=W	ug/g dry	4/1/99
Beryllium	ML-6	0.5	<=W	ug/g dry	4/1/99
Beryllium	ML-7	0.5	<=W	ug/g dry	4/1/99
Beryllium	ML-8	0.5	<=W	ug/g dry	4/1/99
Beryllium	ML-9	0.6	<T	ug/g dry	4/1/99
Beryllium	MR-1	0.5	<=W	ug/g dry	4/1/99
Beryllium	MR-10	0.6	<T	ug/g dry	4/1/99
Beryllium	MR-11	0.7	<T	ug/g dry	4/1/99
Beryllium	MR-12	0.5	<=W	ug/g dry	4/1/99
Beryllium	MR-13	0.6	<T	ug/g dry	4/1/99
Beryllium	MR-14	0.5	<=W	ug/g dry	4/1/99
Beryllium	MR-15	0.5	<=W	ug/g dry	4/1/99
Beryllium	MR-16	0.5	<=W	ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Beryllium	MR-2	0.6	<T	ug/g dry	4/1/99
Beryllium	MR-3	0.5	<=W	ug/g dry	4/1/99
Beryllium	MR-4	0.5	<=W	ug/g dry	4/1/99
Beryllium	MR-5	0.5	<=W	ug/g dry	4/1/99
Beryllium	MR-6	0.5	<=W	ug/g dry	4/1/99
Beryllium	MR-7	0.5	<=W	ug/g dry	4/1/99
Beryllium	MR-8	0.5	<=W	ug/g dry	4/1/99
Beryllium	MR-9	0.6	<T	ug/g dry	4/1/99
Beryllium	RL-1	2.1	<T	ug/g dry	4/1/99
Beryllium	RL-2	2.5		ug/g dry	4/1/99
Beryllium	RL-3	3.1		ug/g dry	4/1/99
Beryllium	RL-4	0.5	<=W	ug/g dry	4/1/99
Beryllium	RL-5	0.5	<=W	ug/g dry	4/1/99
Beryllium	RL-6	0.5	<=W	ug/g dry	4/1/99
Beryllium	RL-7	0.5	<=W	ug/g dry	4/1/99
Beryllium	SKR-1	0.5	<=W	ug/g dry	4/1/99
Beryllium	SL-1	0.5	<=W	ug/g dry	4/1/99
Beryllium	SL-10	0.5	<=W	ug/g dry	4/1/99
Beryllium	SL-11	0.5	<=W	ug/g dry	4/1/99
Beryllium	SL-12	0.5	<=W	ug/g dry	4/1/99
Beryllium	SL-13	0.5	<=W	ug/g dry	4/1/99
Beryllium	SL-14	0.5	<=W	ug/g dry	4/1/99
Beryllium	SL-15	0.5	<=W	ug/g dry	4/1/99
Beryllium	SL-2	0.8	<T	ug/g dry	4/1/99
Beryllium	SL-3	0.5	<=W	ug/g dry	4/1/99
Beryllium	SL-4	0.8	<T	ug/g dry	4/1/99
Beryllium	SL-5	0.7	<T	ug/g dry	4/1/99
Beryllium	SL-6	0.5	<=W	ug/g dry	4/1/99
Beryllium	SL-7	0.5	<=W	ug/g dry	4/1/99
Beryllium	SL-8	0.5	<=W	ug/g dry	4/1/99
Beryllium	SL-9	0.5	<=W	ug/g dry	4/1/99
Beryllium	SR-1	0.5	<=W	ug/g dry	4/1/99
Beryllium	SR-2	0.7	<T	ug/g dry	4/1/99
Beryllium	SR-3	0.8	<T	ug/g dry	4/1/99
Beryllium	YC-1	2.5		ug/g dry	4/1/99
Cadmium	BR-1	0.4	<T	ug/g dry	4/1/99
Cadmium	CL-1	0.2	<=W	ug/g dry	4/1/99
Cadmium	CL-2	0.5	<T	ug/g dry	4/1/99
Cadmium	CL-3	0.2	<=W	ug/g dry	4/1/99
Cadmium	CL-4	0.2	<=W	ug/g dry	4/1/99
Cadmium	CL-5	0.2	<=W	ug/g dry	4/1/99
Cadmium	CL-6	0.2	<=W	ug/g dry	4/1/99
Cadmium	CL-7	0.2	<=W	ug/g dry	4/1/99
Cadmium	CL-8	0.8	<T	ug/g dry	4/1/99
Cadmium	ML-1	3		ug/g dry	4/1/99
Cadmium	ML-10	0.2	<=W	ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Cadmium	ML-11	0.2	<=W	ug/g dry	4/1/99
Cadmium	ML-12	0.5	<T	ug/g dry	4/1/99
Cadmium	ML-13	0.9	<T	ug/g dry	4/1/99
Cadmium	ML-14	0.4	<T	ug/g dry	4/1/99
Cadmium	ML-2	2.6		ug/g dry	4/1/99
Cadmium	ML-3	2.3		ug/g dry	4/1/99
Cadmium	ML-4	0.8	<T	ug/g dry	4/1/99
Cadmium	ML-5	1		ug/g dry	4/1/99
Cadmium	ML-6	1.2		ug/g dry	4/1/99
Cadmium	ML-7	0.5	<T	ug/g dry	4/1/99
Cadmium	ML-8	0.2	<=W	ug/g dry	4/1/99
Cadmium	ML-9	0.5	<T	ug/g dry	4/1/99
Cadmium	MR-1	0.3	<T	ug/g dry	4/1/99
Cadmium	MR-10	1.5		ug/g dry	4/1/99
Cadmium	MR-11	2.6		ug/g dry	4/1/99
Cadmium	MR-12	0.6	<T	ug/g dry	4/1/99
Cadmium	MR-13	2.5		ug/g dry	4/1/99
Cadmium	MR-14	0.8	<T	ug/g dry	4/1/99
Cadmium	MR-15	0.3	<T	ug/g dry	4/1/99
Cadmium	MR-16	0.9	<T	ug/g dry	4/1/99
Cadmium	MR-2	0.2	<=W	ug/g dry	4/1/99
Cadmium	MR-3	0.7	<T	ug/g dry	4/1/99
Cadmium	MR-4	0.3	<T	ug/g dry	4/1/99
Cadmium	MR-5	0.6	<T	ug/g dry	4/1/99
Cadmium	MR-6	0.4	<T	ug/g dry	4/1/99
Cadmium	MR-7	0.5	<T	ug/g dry	4/1/99
Cadmium	MR-8	0.5	<T	ug/g dry	4/1/99
Cadmium	MR-9	1.2		ug/g dry	4/1/99
Cadmium	RL-1	1.9		ug/g dry	4/1/99
Cadmium	RL-2	2.3		ug/g dry	4/1/99
Cadmium	RL-3	0.7	<T	ug/g dry	4/1/99
Cadmium	RL-4	0.3	<T	ug/g dry	4/1/99
Cadmium	RL-5	0.3	<T	ug/g dry	4/1/99
Cadmium	RL-6	0.2	<=W	ug/g dry	4/1/99
Cadmium	RL-7	0.5	<T	ug/g dry	4/1/99
Cadmium	SKR-1	0.3	<T	ug/g dry	4/1/99
Cadmium	SL-1	0.8	<T	ug/g dry	4/1/99
Cadmium	SL-10	0.2	<=W	ug/g dry	4/1/99
Cadmium	SL-11	0.2	<=W	ug/g dry	4/1/99
Cadmium	SL-12	0.2	<=W	ug/g dry	4/1/99
Cadmium	SL-13	0.2	<=W	ug/g dry	4/1/99
Cadmium	SL-14	0.2	<=W	ug/g dry	4/1/99
Cadmium	SL-15	0.3	<T	ug/g dry	4/1/99
Cadmium	SL-2	2.3		ug/g dry	4/1/99
Cadmium	SL-3	0.4	<T	ug/g dry	4/1/99
Cadmium	SL-4	2.2		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Cadmium	SL-5	2.7		ug/g dry	4/1/99
Cadmium	SL-6	0.2	<=W	ug/g dry	4/1/99
Cadmium	SL-7	0.4	<T	ug/g dry	4/1/99
Cadmium	SL-8	0.4	<T	ug/g dry	4/1/99
Cadmium	SL-9	0.7	<T	ug/g dry	4/1/99
Cadmium	SR-1	0.6	<T	ug/g dry	4/1/99
Cadmium	SR-2	0.6	<T	ug/g dry	4/1/99
Cadmium	SR-3	0.6	<T	ug/g dry	4/1/99
Cadmium	YC-1	1.9		ug/g dry	4/1/99
Calcium	BR-1	38000		ug/g dry	4/1/99
Calcium	CL-1	340000		ug/g dry	4/1/99
Calcium	CL-2	270000		ug/g dry	4/1/99
Calcium	CL-3	190000		ug/g dry	4/1/99
Calcium	CL-4	260000		ug/g dry	4/1/99
Calcium	CL-5	270000		ug/g dry	4/1/99
Calcium	CL-6	160000		ug/g dry	4/1/99
Calcium	CL-7	98000		ug/g dry	4/1/99
Calcium	CL-8	200000		ug/g dry	4/1/99
Calcium	ML-1	79000		ug/g dry	4/1/99
Calcium	ML-10	14000		ug/g dry	4/1/99
Calcium	ML-11	11000		ug/g dry	4/1/99
Calcium	ML-12	150000		ug/g dry	4/1/99
Calcium	ML-13	240000		ug/g dry	4/1/99
Calcium	ML-14	120000		ug/g dry	4/1/99
Calcium	ML-2	25000		ug/g dry	4/1/99
Calcium	ML-3	39000		ug/g dry	4/1/99
Calcium	ML-4	13000		ug/g dry	4/1/99
Calcium	ML-5	240000		ug/g dry	4/1/99
Calcium	ML-6	63000		ug/g dry	4/1/99
Calcium	ML-7	280000		ug/g dry	4/1/99
Calcium	ML-8	18000		ug/g dry	4/1/99
Calcium	ML-9	59000		ug/g dry	4/1/99
Calcium	MR-1	6400		ug/g dry	4/1/99
Calcium	MR-10	16000		ug/g dry	4/1/99
Calcium	MR-11	20000		ug/g dry	4/1/99
Calcium	MR-12	6300		ug/g dry	4/1/99
Calcium	MR-13	17000		ug/g dry	4/1/99
Calcium	MR-14	9300		ug/g dry	4/1/99
Calcium	MR-15	5000		ug/g dry	4/1/99
Calcium	MR-16	38000		ug/g dry	4/1/99
Calcium	MR-2	17000		ug/g dry	4/1/99
Calcium	MR-3	8600		ug/g dry	4/1/99
Calcium	MR-4	11000		ug/g dry	4/1/99
Calcium	MR-5	11000		ug/g dry	4/1/99
Calcium	MR-6	13000		ug/g dry	4/1/99
Calcium	MR-7	9400		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Calcium	MR-8	14000		ug/g dry	4/1/99
Calcium	MR-9	13000		ug/g dry	4/1/99
Calcium	RL-1	30000		ug/g dry	4/1/99
Calcium	RL-2	17000		ug/g dry	4/1/99
Calcium	RL-3	16000		ug/g dry	4/1/99
Calcium	RL-4	42000		ug/g dry	4/1/99
Calcium	RL-5	45000		ug/g dry	4/1/99
Calcium	RL-6	26000		ug/g dry	4/1/99
Calcium	RL-7	18000		ug/g dry	4/1/99
Calcium	SKR-1	4600		ug/g dry	4/1/99
Calcium	SL-1	10000		ug/g dry	4/1/99
Calcium	SL-10	6200		ug/g dry	4/1/99
Calcium	SL-11	4600		ug/g dry	4/1/99
Calcium	SL-12	4000		ug/g dry	4/1/99
Calcium	SL-13	3600		ug/g dry	4/1/99
Calcium	SL-14	5300		ug/g dry	4/1/99
Calcium	SL-15	4000		ug/g dry	4/1/99
Calcium	SL-2	11000		ug/g dry	4/1/99
Calcium	SL-3	5700		ug/g dry	4/1/99
Calcium	SL-4	10000		ug/g dry	4/1/99
Calcium	SL-5	9500		ug/g dry	4/1/99
Calcium	SL-6	41000		ug/g dry	4/1/99
Calcium	SL-7	34000		ug/g dry	4/1/99
Calcium	SL-8	9400		ug/g dry	4/1/99
Calcium	SL-9	13000		ug/g dry	4/1/99
Calcium	SR-1	17000		ug/g dry	4/1/99
Calcium	SR-2	25000		ug/g dry	4/1/99
Calcium	SR-3	9400		ug/g dry	4/1/99
Calcium	YC-1	9300		ug/g dry	4/1/99
Chromium	BR-1	18		ug/g dry	4/1/99
Chromium	CL-1	1	<=W	ug/g dry	4/1/99
Chromium	CL-2	8		ug/g dry	4/1/99
Chromium	CL-3	7		ug/g dry	4/1/99
Chromium	CL-4	3	<T	ug/g dry	4/1/99
Chromium	CL-5	1	<=W	ug/g dry	4/1/99
Chromium	CL-6	4	<T	ug/g dry	4/1/99
Chromium	CL-7	4	<T	ug/g dry	4/1/99
Chromium	CL-8	15		ug/g dry	4/1/99
Chromium	ML-1	29		ug/g dry	4/1/99
Chromium	ML-10	13		ug/g dry	4/1/99
Chromium	ML-11	11		ug/g dry	4/1/99
Chromium	ML-12	11		ug/g dry	4/1/99
Chromium	ML-13	7		ug/g dry	4/1/99
Chromium	ML-14	7		ug/g dry	4/1/99
Chromium	ML-2	38		ug/g dry	4/1/99
Chromium	ML-3	27		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Chromium	ML-4	19		ug/g dry	4/1/99
Chromium	ML-5	10		ug/g dry	4/1/99
Chromium	ML-6	13		ug/g dry	4/1/99
Chromium	ML-7	5		ug/g dry	4/1/99
Chromium	ML-8	10		ug/g dry	4/1/99
Chromium	ML-9	27		ug/g dry	4/1/99
Chromium	MR-1	18		ug/g dry	4/1/99
Chromium	MR-10	35		ug/g dry	4/1/99
Chromium	MR-11	50		ug/g dry	4/1/99
Chromium	MR-12	18		ug/g dry	4/1/99
Chromium	MR-13	35		ug/g dry	4/1/99
Chromium	MR-14	21		ug/g dry	4/1/99
Chromium	MR-15	10		ug/g dry	4/1/99
Chromium	MR-16	22		ug/g dry	4/1/99
Chromium	MR-2	27		ug/g dry	4/1/99
Chromium	MR-3	24		ug/g dry	4/1/99
Chromium	MR-4	78		ug/g dry	4/1/99
Chromium	MR-5	59		ug/g dry	4/1/99
Chromium	MR-6	55		ug/g dry	4/1/99
Chromium	MR-7	65		ug/g dry	4/1/99
Chromium	MR-8	61		ug/g dry	4/1/99
Chromium	MR-9	40		ug/g dry	4/1/99
Chromium	RL-1	18		ug/g dry	4/1/99
Chromium	RL-2	31		ug/g dry	4/1/99
Chromium	RL-3	32		ug/g dry	4/1/99
Chromium	RL-4	8		ug/g dry	4/1/99
Chromium	RL-5	9		ug/g dry	4/1/99
Chromium	RL-6	11		ug/g dry	4/1/99
Chromium	RL-7	15		ug/g dry	4/1/99
Chromium	SKR-1	18		ug/g dry	4/1/99
Chromium	SL-1	29		ug/g dry	4/1/99
Chromium	SL-10	9		ug/g dry	4/1/99
Chromium	SL-11	7		ug/g dry	4/1/99
Chromium	SL-12	12		ug/g dry	4/1/99
Chromium	SL-13	6		ug/g dry	4/1/99
Chromium	SL-14	9		ug/g dry	4/1/99
Chromium	SL-15	8		ug/g dry	4/1/99
Chromium	SL-2	50		ug/g dry	4/1/99
Chromium	SL-3	18		ug/g dry	4/1/99
Chromium	SL-4	48		ug/g dry	4/1/99
Chromium	SL-5	43		ug/g dry	4/1/99
Chromium	SL-6	18		ug/g dry	4/1/99
Chromium	SL-7	25		ug/g dry	4/1/99
Chromium	SL-8	19		ug/g dry	4/1/99
Chromium	SL-9	27		ug/g dry	4/1/99
Chromium	SR-1	26		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Chromium	SR-2	32		ug/g dry	4/1/99
Chromium	SR-3	38		ug/g dry	4/1/99
Chromium	YC-1	110		ug/g dry	4/1/99
Cobalt	BR-1	7.1		ug/g dry	4/1/99
Cobalt	CL-1	0.5	<=W	ug/g dry	4/1/99
Cobalt	CL-2	2.9		ug/g dry	4/1/99
Cobalt	CL-3	2.2	<T	ug/g dry	4/1/99
Cobalt	CL-4	1	<T	ug/g dry	4/1/99
Cobalt	CL-5	0.7	<T	ug/g dry	4/1/99
Cobalt	CL-6	1.2	<T	ug/g dry	4/1/99
Cobalt	CL-7	0.8	<T	ug/g dry	4/1/99
Cobalt	CL-8	6.3		ug/g dry	4/1/99
Cobalt	ML-1	770		ug/g dry	4/1/99
Cobalt	ML-10	26		ug/g dry	4/1/99
Cobalt	ML-11	47		ug/g dry	4/1/99
Cobalt	ML-12	140		ug/g dry	4/1/99
Cobalt	ML-13	350		ug/g dry	4/1/99
Cobalt	ML-14	68		ug/g dry	4/1/99
Cobalt	ML-2	760		ug/g dry	4/1/99
Cobalt	ML-3	760		ug/g dry	4/1/99
Cobalt	ML-4	420		ug/g dry	4/1/99
Cobalt	ML-5	420		ug/g dry	4/1/99
Cobalt	ML-6	250		ug/g dry	4/1/99
Cobalt	ML-7	190		ug/g dry	4/1/99
Cobalt	ML-8	39		ug/g dry	4/1/99
Cobalt	ML-9	83		ug/g dry	4/1/99
Cobalt	MR-1	5.6		ug/g dry	4/1/99
Cobalt	MR-10	740		ug/g dry	4/1/99
Cobalt	MR-11	1100		ug/g dry	4/1/99
Cobalt	MR-12	45		ug/g dry	4/1/99
Cobalt	MR-13	150		ug/g dry	4/1/99
Cobalt	MR-14	55		ug/g dry	4/1/99
Cobalt	MR-15	33		ug/g dry	4/1/99
Cobalt	MR-16	38		ug/g dry	4/1/99
Cobalt	MR-2	7.5		ug/g dry	4/1/99
Cobalt	MR-3	9		ug/g dry	4/1/99
Cobalt	MR-4	25		ug/g dry	4/1/99
Cobalt	MR-5	140		ug/g dry	4/1/99
Cobalt	MR-6	240		ug/g dry	4/1/99
Cobalt	MR-7	450		ug/g dry	4/1/99
Cobalt	MR-8	440		ug/g dry	4/1/99
Cobalt	MR-9	540		ug/g dry	4/1/99
Cobalt	RL-1	12		ug/g dry	4/1/99
Cobalt	RL-2	14		ug/g dry	4/1/99
Cobalt	RL-3	15		ug/g dry	4/1/99
Cobalt	RL-4	3.7		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Cobalt	RL-5	3.4		ug/g dry	4/1/99
Cobalt	RL-6	3.5		ug/g dry	4/1/99
Cobalt	RL-7	4.9		ug/g dry	4/1/99
Cobalt	SKR-1	6.3		ug/g dry	4/1/99
Cobalt	SL-1	68		ug/g dry	4/1/99
Cobalt	SL-10	5.2		ug/g dry	4/1/99
Cobalt	SL-11	6.2		ug/g dry	4/1/99
Cobalt	SL-12	3		ug/g dry	4/1/99
Cobalt	SL-13	3.7		ug/g dry	4/1/99
Cobalt	SL-14	3.9		ug/g dry	4/1/99
Cobalt	SL-15	6.4		ug/g dry	4/1/99
Cobalt	SL-2	200		ug/g dry	4/1/99
Cobalt	SL-3	77		ug/g dry	4/1/99
Cobalt	SL-4	140		ug/g dry	4/1/99
Cobalt	SL-5	76		ug/g dry	4/1/99
Cobalt	SL-6	4.6		ug/g dry	4/1/99
Cobalt	SL-7	12		ug/g dry	4/1/99
Cobalt	SL-8	12		ug/g dry	4/1/99
Cobalt	SL-9	20		ug/g dry	4/1/99
Cobalt	SR-1	8.5		ug/g dry	4/1/99
Cobalt	SR-2	8		ug/g dry	4/1/99
Cobalt	SR-3	9		ug/g dry	4/1/99
Cobalt	YC-1	1600		ug/g dry	4/1/99
Copper	BR-1	6		ug/g dry	4/1/99
Copper	CL-1	3	<T	ug/g dry	4/1/99
Copper	CL-2	8		ug/g dry	4/1/99
Copper	CL-3	4	<T	ug/g dry	4/1/99
Copper	CL-4	3	<T	ug/g dry	4/1/99
Copper	CL-5	2	<T	ug/g dry	4/1/99
Copper	CL-6	1	<=W	ug/g dry	4/1/99
Copper	CL-7	1	<=W	ug/g dry	4/1/99
Copper	CL-8	20		ug/g dry	4/1/99
Copper	ML-1	170		ug/g dry	4/1/99
Copper	ML-10	3	<T	ug/g dry	4/1/99
Copper	ML-11	3	<T	ug/g dry	4/1/99
Copper	ML-12	31		ug/g dry	4/1/99
Copper	ML-13	51		ug/g dry	4/1/99
Copper	ML-14	9		ug/g dry	4/1/99
Copper	ML-2	180		ug/g dry	4/1/99
Copper	ML-3	160		ug/g dry	4/1/99
Copper	ML-4	46		ug/g dry	4/1/99
Copper	ML-5	41		ug/g dry	4/1/99
Copper	ML-6	52		ug/g dry	4/1/99
Copper	ML-7	36		ug/g dry	4/1/99
Copper	ML-8	5		ug/g dry	4/1/99
Copper	ML-9	27		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Copper	MR-1	6		ug/g dry	4/1/99
Copper	MR-10	100		ug/g dry	4/1/99
Copper	MR-11	190		ug/g dry	4/1/99
Copper	MR-12	10		ug/g dry	4/1/99
Copper	MR-13	40		ug/g dry	4/1/99
Copper	MR-14	13		ug/g dry	4/1/99
Copper	MR-15	4	<T	ug/g dry	4/1/99
Copper	MR-16	35		ug/g dry	4/1/99
Copper	MR-2	12		ug/g dry	4/1/99
Copper	MR-3	11		ug/g dry	4/1/99
Copper	MR-4	23		ug/g dry	4/1/99
Copper	MR-5	39		ug/g dry	4/1/99
Copper	MR-6	78		ug/g dry	4/1/99
Copper	MR-7	110		ug/g dry	4/1/99
Copper	MR-8	75		ug/g dry	4/1/99
Copper	MR-9	98		ug/g dry	4/1/99
Copper	RL-1	33		ug/g dry	4/1/99
Copper	RL-2	43		ug/g dry	4/1/99
Copper	RL-3	40		ug/g dry	4/1/99
Copper	RL-4	6		ug/g dry	4/1/99
Copper	RL-5	7		ug/g dry	4/1/99
Copper	RL-6	8		ug/g dry	4/1/99
Copper	RL-7	14		ug/g dry	4/1/99
Copper	SKR-1	6		ug/g dry	4/1/99
Copper	SL-1	20		ug/g dry	4/1/99
Copper	SL-10	1	<=W	ug/g dry	4/1/99
Copper	SL-11	1	<=W	ug/g dry	4/1/99
Copper	SL-12	1	<=W	ug/g dry	4/1/99
Copper	SL-13	1	<=W	ug/g dry	4/1/99
Copper	SL-14	1	<=W	ug/g dry	4/1/99
Copper	SL-15	2	<T	ug/g dry	4/1/99
Copper	SL-2	43		ug/g dry	4/1/99
Copper	SL-3	4	<T	ug/g dry	4/1/99
Copper	SL-4	45		ug/g dry	4/1/99
Copper	SL-5	52		ug/g dry	4/1/99
Copper	SL-6	11		ug/g dry	4/1/99
Copper	SL-7	22		ug/g dry	4/1/99
Copper	SL-8	11		ug/g dry	4/1/99
Copper	SL-9	21		ug/g dry	4/1/99
Copper	SR-1	23		ug/g dry	4/1/99
Copper	SR-2	16		ug/g dry	4/1/99
Copper	SR-3	18		ug/g dry	4/1/99
Copper	YC-1	3200		ug/g dry	4/1/99
Iron	BR-1	13000		ug/g dry	4/1/99
Iron	CL-1	2200		ug/g dry	4/1/99
Iron	CL-2	6800		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Iron	CL-3	5500		ug/g dry	4/1/99
Iron	CL-4	2300		ug/g dry	4/1/99
Iron	CL-5	1300		ug/g dry	4/1/99
Iron	CL-6	3400		ug/g dry	4/1/99
Iron	CL-7	3100		ug/g dry	4/1/99
Iron	CL-8	12000		ug/g dry	4/1/99
Iron	ML-1	28000		ug/g dry	4/1/99
Iron	ML-10	7900		ug/g dry	4/1/99
Iron	ML-11	6300		ug/g dry	4/1/99
Iron	ML-12	11000		ug/g dry	4/1/99
Iron	ML-13	9100		ug/g dry	4/1/99
Iron	ML-14	5600		ug/g dry	4/1/99
Iron	ML-2	32000		ug/g dry	4/1/99
Iron	ML-3	36000		ug/g dry	4/1/99
Iron	ML-4	42000		ug/g dry	4/1/99
Iron	ML-5	13000		ug/g dry	4/1/99
Iron	ML-6	11000		ug/g dry	4/1/99
Iron	ML-7	6300		ug/g dry	4/1/99
Iron	ML-8	8800		ug/g dry	4/1/99
Iron	ML-9	21000		ug/g dry	4/1/99
Iron	MR-1	14000		ug/g dry	4/1/99
Iron	MR-10	28000		ug/g dry	4/1/99
Iron	MR-11	37000		ug/g dry	4/1/99
Iron	MR-12	16000		ug/g dry	4/1/99
Iron	MR-13	21000		ug/g dry	4/1/99
Iron	MR-14	21000		ug/g dry	4/1/99
Iron	MR-15	9300		ug/g dry	4/1/99
Iron	MR-16	21000		ug/g dry	4/1/99
Iron	MR-2	22000		ug/g dry	4/1/99
Iron	MR-3	20000		ug/g dry	4/1/99
Iron	MR-4	28000		ug/g dry	4/1/99
Iron	MR-5	26000		ug/g dry	4/1/99
Iron	MR-6	30000		ug/g dry	4/1/99
Iron	MR-7	35000		ug/g dry	4/1/99
Iron	MR-8	36000		ug/g dry	4/1/99
Iron	MR-9	26000		ug/g dry	4/1/99
Iron	RL-1	29000		ug/g dry	4/1/99
Iron	RL-2	60000		ug/g dry	4/1/99
Iron	RL-3	44000		ug/g dry	4/1/99
Iron	RL-4	8900		ug/g dry	4/1/99
Iron	RL-5	9600		ug/g dry	4/1/99
Iron	RL-6	12000		ug/g dry	4/1/99
Iron	RL-7	14000		ug/g dry	4/1/99
Iron	SKR-1	14000		ug/g dry	4/1/99
Iron	SL-1	25000		ug/g dry	4/1/99
Iron	SL-10	6800		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Iron	SL-11	5300		ug/g dry	4/1/99
Iron	SL-12	8600		ug/g dry	4/1/99
Iron	SL-13	5500		ug/g dry	4/1/99
Iron	SL-14	5800		ug/g dry	4/1/99
Iron	SL-15	4800		ug/g dry	4/1/99
Iron	SL-2	52000		ug/g dry	4/1/99
Iron	SL-3	32000		ug/g dry	4/1/99
Iron	SL-4	56000		ug/g dry	4/1/99
Iron	SL-5	45000		ug/g dry	4/1/99
Iron	SL-6	11000		ug/g dry	4/1/99
Iron	SL-7	15000		ug/g dry	4/1/99
Iron	SL-8	12000		ug/g dry	4/1/99
Iron	SL-9	18000		ug/g dry	4/1/99
Iron	SR-1	16000		ug/g dry	4/1/99
Iron	SR-2	18000		ug/g dry	4/1/99
Iron	SR-3	24000		ug/g dry	4/1/99
Iron	YC-1	26000		ug/g dry	4/1/99
Lead	BR-1	4	<T	ug/g dry	4/1/99
Lead	CL-1	4	<T	ug/g dry	4/1/99
Lead	CL-2	23		ug/g dry	4/1/99
Lead	CL-3	11		ug/g dry	4/1/99
Lead	CL-4	6	<T	ug/g dry	4/1/99
Lead	CL-5	2	<=W	ug/g dry	4/1/99
Lead	CL-6	2	<=W	ug/g dry	4/1/99
Lead	CL-7	2	<=W	ug/g dry	4/1/99
Lead	CL-8	49		ug/g dry	4/1/99
Lead	ML-1	81		ug/g dry	4/1/99
Lead	ML-10	6	<T	ug/g dry	4/1/99
Lead	ML-11	7	<T	ug/g dry	4/1/99
Lead	ML-12	18		ug/g dry	4/1/99
Lead	ML-13	18		ug/g dry	4/1/99
Lead	ML-14	7	<T	ug/g dry	4/1/99
Lead	ML-2	92		ug/g dry	4/1/99
Lead	ML-3	140		ug/g dry	4/1/99
Lead	ML-4	40		ug/g dry	4/1/99
Lead	ML-5	27		ug/g dry	4/1/99
Lead	ML-6	27		ug/g dry	4/1/99
Lead	ML-7	30		ug/g dry	4/1/99
Lead	ML-8	5	<T	ug/g dry	4/1/99
Lead	ML-9	16		ug/g dry	4/1/99
Lead	MR-1	3	<T	ug/g dry	4/1/99
Lead	MR-10	28		ug/g dry	4/1/99
Lead	MR-11	66		ug/g dry	4/1/99
Lead	MR-12	11		ug/g dry	4/1/99
Lead	MR-13	51		ug/g dry	4/1/99
Lead	MR-14	26		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Lead	MR-15	9	<T	ug/g dry	4/1/99
Lead	MR-16	69		ug/g dry	4/1/99
Lead	MR-2	5	<T	ug/g dry	4/1/99
Lead	MR-3	8	<T	ug/g dry	4/1/99
Lead	MR-4	11		ug/g dry	4/1/99
Lead	MR-5	25		ug/g dry	4/1/99
Lead	MR-6	25		ug/g dry	4/1/99
Lead	MR-7	22		ug/g dry	4/1/99
Lead	MR-8	20		ug/g dry	4/1/99
Lead	MR-9	24		ug/g dry	4/1/99
Lead	RL-1	71		ug/g dry	4/1/99
Lead	RL-2	140		ug/g dry	4/1/99
Lead	RL-3	20		ug/g dry	4/1/99
Lead	RL-4	6	<T	ug/g dry	4/1/99
Lead	RL-5	8	<T	ug/g dry	4/1/99
Lead	RL-6	15		ug/g dry	4/1/99
Lead	RL-7	47		ug/g dry	4/1/99
Lead	SKR-1	6	<T	ug/g dry	4/1/99
Lead	SL-1	29		ug/g dry	4/1/99
Lead	SL-10	3	<T	ug/g dry	4/1/99
Lead	SL-11	3	<T	ug/g dry	4/1/99
Lead	SL-12	3	<T	ug/g dry	4/1/99
Lead	SL-13	2	<=W	ug/g dry	4/1/99
Lead	SL-14	2	<=W	ug/g dry	4/1/99
Lead	SL-15	4	<T	ug/g dry	4/1/99
Lead	SL-2	84		ug/g dry	4/1/99
Lead	SL-3	14		ug/g dry	4/1/99
Lead	SL-4	78		ug/g dry	4/1/99
Lead	SL-5	71		ug/g dry	4/1/99
Lead	SL-6	15		ug/g dry	4/1/99
Lead	SL-7	30		ug/g dry	4/1/99
Lead	SL-8	9	<T	ug/g dry	4/1/99
Lead	SL-9	16		ug/g dry	4/1/99
Lead	SR-1	30		ug/g dry	4/1/99
Lead	SR-2	39		ug/g dry	4/1/99
Lead	SR-3	32		ug/g dry	4/1/99
Lead	YC-1	56		ug/g dry	4/1/99
LOI	BR-1	35		mg/g dry	4/1/99
LOI	CL-1	200		mg/g dry	4/1/99
LOI	CL-2	180		mg/g dry	4/1/99
LOI	CL-3	170		mg/g dry	4/1/99
LOI	CL-4	180		mg/g dry	4/1/99
LOI	CL-5	190		mg/g dry	4/1/99
LOI	CL-6	180		mg/g dry	4/1/99
LOI	CL-7	120		mg/g dry	4/1/99
LOI	CL-8	160		mg/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
LOI	ML-1	540		mg/g dry	4/1/99
LOI	ML-10	28		mg/g dry	4/1/99
LOI	ML-11	28		mg/g dry	4/1/99
LOI	ML-12	430		mg/g dry	4/1/99
LOI	ML-13	790		mg/g dry	4/1/99
LOI	ML-14	360		mg/g dry	4/1/99
LOI	ML-2	150		mg/g dry	4/1/99
LOI	ML-3	170		mg/g dry	4/1/99
LOI	ML-4	60		mg/g dry	4/1/99
LOI	ML-5	630		mg/g dry	4/1/99
LOI	ML-6	240		mg/g dry	4/1/99
LOI	ML-7	790		mg/g dry	4/1/99
LOI	ML-8	49		mg/g dry	4/1/99
LOI	ML-9	180		mg/g dry	4/1/99
LOI	MR-1	21		mg/g dry	4/1/99
LOI	MR-10	100		mg/g dry	4/1/99
LOI	MR-11	110		mg/g dry	4/1/99
LOI	MR-12	31		mg/g dry	4/1/99
LOI	MR-13	90		mg/g dry	4/1/99
LOI	MR-14	52		mg/g dry	4/1/99
LOI	MR-15	26		mg/g dry	4/1/99
LOI	MR-16	89		mg/g dry	4/1/99
LOI	MR-2	35		mg/g dry	4/1/99
LOI	MR-3	29		mg/g dry	4/1/99
LOI	MR-4	74		mg/g dry	4/1/99
LOI	MR-5	50		mg/g dry	4/1/99
LOI	MR-6	53		mg/g dry	4/1/99
LOI	MR-7	48		mg/g dry	4/1/99
LOI	MR-8	59		mg/g dry	4/1/99
LOI	MR-9	86		mg/g dry	4/1/99
LOI	RL-1	82		mg/g dry	4/1/99
LOI	RL-2	73		mg/g dry	4/1/99
LOI	RL-3	63		mg/g dry	4/1/99
LOI	RL-4	95		mg/g dry	4/1/99
LOI	RL-5	100		mg/g dry	4/1/99
LOI	RL-6	40		mg/g dry	4/1/99
LOI	RL-7	39		mg/g dry	4/1/99
LOI	SKR-1	20		mg/g dry	4/1/99
LOI	SL-1	57		mg/g dry	4/1/99
LOI	SL-10	18		mg/g dry	4/1/99
LOI	SL-11	14		mg/g dry	4/1/99
LOI	SL-12	16		mg/g dry	4/1/99
LOI	SL-13	15		mg/g dry	4/1/99
LOI	SL-14	18		mg/g dry	4/1/99
LOI	SL-15	16		mg/g dry	4/1/99
LOI	SL-2	82		mg/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
LOI	SL-3	31		mg/g dry	4/1/99
LOI	SL-4	92		mg/g dry	4/1/99
LOI	SL-5	77		mg/g dry	4/1/99
LOI	SL-6	64		mg/g dry	4/1/99
LOI	SL-7	78		mg/g dry	4/1/99
LOI	SL-8	48		mg/g dry	4/1/99
LOI	SL-9	73		mg/g dry	4/1/99
LOI	SR-1	160		mg/g dry	4/1/99
LOI	SR-2	190		mg/g dry	4/1/99
LOI	SR-3	85		mg/g dry	4/1/99
LOI	YC-1	60		mg/g dry	4/1/99
Magnesium	BR-1	14000		ug/g dry	4/1/99
Magnesium	CL-1	1100		ug/g dry	4/1/99
Magnesium	CL-2	2600		ug/g dry	4/1/99
Magnesium	CL-3	5100		ug/g dry	4/1/99
Magnesium	CL-4	2300		ug/g dry	4/1/99
Magnesium	CL-5	1800		ug/g dry	4/1/99
Magnesium	CL-6	4700		ug/g dry	4/1/99
Magnesium	CL-7	5400		ug/g dry	4/1/99
Magnesium	CL-8	4200		ug/g dry	4/1/99
Magnesium	ML-1	6500		ug/g dry	4/1/99
Magnesium	ML-10	4400		ug/g dry	4/1/99
Magnesium	ML-11	3000		ug/g dry	4/1/99
Magnesium	ML-12	14000		ug/g dry	4/1/99
Magnesium	ML-13	6500		ug/g dry	4/1/99
Magnesium	ML-14	5200		ug/g dry	4/1/99
Magnesium	ML-2	8200		ug/g dry	4/1/99
Magnesium	ML-3	6300		ug/g dry	4/1/99
Magnesium	ML-4	4000		ug/g dry	4/1/99
Magnesium	ML-5	2800		ug/g dry	4/1/99
Magnesium	ML-6	3200		ug/g dry	4/1/99
Magnesium	ML-7	2500		ug/g dry	4/1/99
Magnesium	ML-8	4400		ug/g dry	4/1/99
Magnesium	ML-9	7400		ug/g dry	4/1/99
Magnesium	MR-1	4600		ug/g dry	4/1/99
Magnesium	MR-10	8000		ug/g dry	4/1/99
Magnesium	MR-11	9000		ug/g dry	4/1/99
Magnesium	MR-12	3900		ug/g dry	4/1/99
Magnesium	MR-13	7000		ug/g dry	4/1/99
Magnesium	MR-14	3800		ug/g dry	4/1/99
Magnesium	MR-15	2500		ug/g dry	4/1/99
Magnesium	MR-16	5900		ug/g dry	4/1/99
Magnesium	MR-2	7400		ug/g dry	4/1/99
Magnesium	MR-3	6800		ug/g dry	4/1/99
Magnesium	MR-4	12000		ug/g dry	4/1/99
Magnesium	MR-5	10000		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Magnesium	MR-6	8700		ug/g dry	4/1/99
Magnesium	MR-7	9800		ug/g dry	4/1/99
Magnesium	MR-8	9300		ug/g dry	4/1/99
Magnesium	MR-9	7700		ug/g dry	4/1/99
Magnesium	RL-1	3600		ug/g dry	4/1/99
Magnesium	RL-2	6500		ug/g dry	4/1/99
Magnesium	RL-3	8500		ug/g dry	4/1/99
Magnesium	RL-4	5600		ug/g dry	4/1/99
Magnesium	RL-5	5500		ug/g dry	4/1/99
Magnesium	RL-6	5200		ug/g dry	4/1/99
Magnesium	RL-7	5400		ug/g dry	4/1/99
Magnesium	SKR-1	3300		ug/g dry	4/1/99
Magnesium	SL-1	6600		ug/g dry	4/1/99
Magnesium	SL-10	2900		ug/g dry	4/1/99
Magnesium	SL-11	1700		ug/g dry	4/1/99
Magnesium	SL-12	1500		ug/g dry	4/1/99
Magnesium	SL-13	1200		ug/g dry	4/1/99
Magnesium	SL-14	1600		ug/g dry	4/1/99
Magnesium	SL-15	1400		ug/g dry	4/1/99
Magnesium	SL-2	8900		ug/g dry	4/1/99
Magnesium	SL-3	1800		ug/g dry	4/1/99
Magnesium	SL-4	8100		ug/g dry	4/1/99
Magnesium	SL-5	8300		ug/g dry	4/1/99
Magnesium	SL-6	6900		ug/g dry	4/1/99
Magnesium	SL-7	7600		ug/g dry	4/1/99
Magnesium	SL-8	4600		ug/g dry	4/1/99
Magnesium	SL-9	6400		ug/g dry	4/1/99
Magnesium	SR-1	7600		ug/g dry	4/1/99
Magnesium	SR-2	8300		ug/g dry	4/1/99
Magnesium	SR-3	8300		ug/g dry	4/1/99
Magnesium	YC-1	4400		ug/g dry	4/1/99
Manganese	BR-1	880		ug/g dry	4/1/99
Manganese	CL-1	850		ug/g dry	4/1/99
Manganese	CL-2	810		ug/g dry	4/1/99
Manganese	CL-3	370		ug/g dry	4/1/99
Manganese	CL-4	370		ug/g dry	4/1/99
Manganese	CL-5	400		ug/g dry	4/1/99
Manganese	CL-6	190		ug/g dry	4/1/99
Manganese	CL-7	150		ug/g dry	4/1/99
Manganese	CL-8	520		ug/g dry	4/1/99
Manganese	ML-1	1100		ug/g dry	4/1/99
Manganese	ML-10	140		ug/g dry	4/1/99
Manganese	ML-11	130		ug/g dry	4/1/99
Manganese	ML-12	460		ug/g dry	4/1/99
Manganese	ML-13	640		ug/g dry	4/1/99
Manganese	ML-14	250		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Manganese	ML-2	1100		ug/g dry	4/1/99
Manganese	ML-3	540		ug/g dry	4/1/99
Manganese	ML-4	780		ug/g dry	4/1/99
Manganese	ML-5	570		ug/g dry	4/1/99
Manganese	ML-6	710		ug/g dry	4/1/99
Manganese	ML-7	630		ug/g dry	4/1/99
Manganese	ML-8	230		ug/g dry	4/1/99
Manganese	ML-9	950		ug/g dry	4/1/99
Manganese	MR-1	230		ug/g dry	4/1/99
Manganese	MR-10	1400		ug/g dry	4/1/99
Manganese	MR-11	1200		ug/g dry	4/1/99
Manganese	MR-12	390		ug/g dry	4/1/99
Manganese	MR-13	580		ug/g dry	4/1/99
Manganese	MR-14	660		ug/g dry	4/1/99
Manganese	MR-15	330		ug/g dry	4/1/99
Manganese	MR-16	1300		ug/g dry	4/1/99
Manganese	MR-2	600		ug/g dry	4/1/99
Manganese	MR-3	1400		ug/g dry	4/1/99
Manganese	MR-4	1600		ug/g dry	4/1/99
Manganese	MR-5	820		ug/g dry	4/1/99
Manganese	MR-6	720		ug/g dry	4/1/99
Manganese	MR-7	520		ug/g dry	4/1/99
Manganese	MR-8	1400		ug/g dry	4/1/99
Manganese	MR-9	730		ug/g dry	4/1/99
Manganese	RL-1	1500		ug/g dry	4/1/99
Manganese	RL-2	1600		ug/g dry	4/1/99
Manganese	RL-3	1800		ug/g dry	4/1/99
Manganese	RL-4	240		ug/g dry	4/1/99
Manganese	RL-5	320		ug/g dry	4/1/99
Manganese	RL-6	220		ug/g dry	4/1/99
Manganese	RL-7	490		ug/g dry	4/1/99
Manganese	SKR-1	600		ug/g dry	4/1/99
Manganese	SL-1	940		ug/g dry	4/1/99
Manganese	SL-10	220		ug/g dry	4/1/99
Manganese	SL-11	250		ug/g dry	4/1/99
Manganese	SL-12	180		ug/g dry	4/1/99
Manganese	SL-13	150		ug/g dry	4/1/99
Manganese	SL-14	190		ug/g dry	4/1/99
Manganese	SL-15	160		ug/g dry	4/1/99
Manganese	SL-2	2100		ug/g dry	4/1/99
Manganese	SL-3	2000		ug/g dry	4/1/99
Manganese	SL-4	1900		ug/g dry	4/1/99
Manganese	SL-5	1500		ug/g dry	4/1/99
Manganese	SL-6	430		ug/g dry	4/1/99
Manganese	SL-7	510		ug/g dry	4/1/99
Manganese	SL-8	370		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Manganese	SL-9	760		ug/g dry	4/1/99
Manganese	SR-1	470		ug/g dry	4/1/99
Manganese	SR-2	270		ug/g dry	4/1/99
Manganese	SR-3	330		ug/g dry	4/1/99
Manganese	YC-1	380		ug/g dry	4/1/99
Mercury	BR-1	0.03	<T	ug/g dry	4/1/99
Mercury	CL-1	0.01	<=W	ug/g dry	4/1/99
Mercury	CL-2	0.03	<T	ug/g dry	4/1/99
Mercury	CL-3	0.01	<=W	ug/g dry	4/1/99
Mercury	CL-4	0.01	<=W	ug/g dry	4/1/99
Mercury	CL-5	0.01	<=W	ug/g dry	4/1/99
Mercury	CL-6	0.01	<=W	ug/g dry	4/1/99
Mercury	CL-7	0.01	<=W	ug/g dry	4/1/99
Mercury	CL-8	0.06		ug/g dry	4/1/99
Mercury	ML-1	0.82		ug/g dry	4/1/99
Mercury	ML-10	0.01	<=W	ug/g dry	4/1/99
Mercury	ML-11	0.01	<=W	ug/g dry	4/1/99
Mercury	ML-12	0.03	<T	ug/g dry	4/1/99
Mercury	ML-13	0.06		ug/g dry	4/1/99
Mercury	ML-14	0.02	<T	ug/g dry	4/1/99
Mercury	ML-2	1		ug/g dry	4/1/99
Mercury	ML-3	0.44		ug/g dry	4/1/99
Mercury	ML-4	0.19		ug/g dry	4/1/99
Mercury	ML-5	0.11		ug/g dry	4/1/99
Mercury	ML-6	0.13		ug/g dry	4/1/99
Mercury	ML-7	0.04	<T	ug/g dry	4/1/99
Mercury	ML-8	0.01	<=W	ug/g dry	4/1/99
Mercury	ML-9	0.09		ug/g dry	4/1/99
Mercury	MR-1	0.02	<T	ug/g dry	4/1/99
Mercury	MR-10	0.95		ug/g dry	4/1/99
Mercury	MR-11	1.8		ug/g dry	4/1/99
Mercury	MR-12	0.05		ug/g dry	4/1/99
Mercury	MR-13	0.17		ug/g dry	4/1/99
Mercury	MR-14	0.19		ug/g dry	4/1/99
Mercury	MR-15	0.03	<T	ug/g dry	4/1/99
Mercury	MR-16	0.17		ug/g dry	4/1/99
Mercury	MR-2	0.02	<T	ug/g dry	4/1/99
Mercury	MR-3	0.18		ug/g dry	4/1/99
Mercury	MR-4	0.43		ug/g dry	4/1/99
Mercury	MR-5	1.4		ug/g dry	4/1/99
Mercury	MR-6	1		ug/g dry	4/1/99
Mercury	MR-7	1.4		ug/g dry	4/1/99
Mercury	MR-8	0.8		ug/g dry	4/1/99
Mercury	MR-9	1.5		ug/g dry	4/1/99
Mercury	RL-1	0.17		ug/g dry	4/1/99
Mercury	RL-2	0.18		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Mercury	RL-3	0.1		ug/g dry	4/1/99
Mercury	RL-4	0.02	<T	ug/g dry	4/1/99
Mercury	RL-5	0.03	<T	ug/g dry	4/1/99
Mercury	RL-6	0.01	<=W	ug/g dry	4/1/99
Mercury	RL-7	0.07		ug/g dry	4/1/99
Mercury	SKR-1	0.02	<T	ug/g dry	4/1/99
Mercury	SL-1	0.06		ug/g dry	4/1/99
Mercury	SL-10	0.01	<=W	ug/g dry	4/1/99
Mercury	SL-11	0.01	<=W	ug/g dry	4/1/99
Mercury	SL-12	0.01	<=W	ug/g dry	4/1/99
Mercury	SL-13	0.01	<=W	ug/g dry	4/1/99
Mercury	SL-14	0.01	<=W	ug/g dry	4/1/99
Mercury	SL-15	0.02	<T	ug/g dry	4/1/99
Mercury	SL-2	0.16		ug/g dry	4/1/99
Mercury	SL-3	0.02	<T	ug/g dry	4/1/99
Mercury	SL-4	0.17		ug/g dry	4/1/99
Mercury	SL-5	0.1		ug/g dry	4/1/99
Mercury	SL-6	0.01	<=W	ug/g dry	4/1/99
Mercury	SL-7	0.01	<=W	ug/g dry	4/1/99
Mercury	SL-8	0.02	<T	ug/g dry	4/1/99
Mercury	SL-9	0.05		ug/g dry	4/1/99
Mercury	SR-1	0.09		ug/g dry	4/1/99
Mercury	SR-2	0.07		ug/g dry	4/1/99
Mercury	SR-3	0.08		ug/g dry	4/1/99
Mercury	YC-1	0.45		ug/g dry	4/1/99
Molybdenum	BR-1	0.5	<=W	ug/g dry	4/1/99
Molybdenum	CL-1	0.5	<=W	ug/g dry	4/1/99
Molybdenum	CL-2	0.6	<T	ug/g dry	4/1/99
Molybdenum	CL-3	0.5	<=W	ug/g dry	4/1/99
Molybdenum	CL-4	0.5	<=W	ug/g dry	4/1/99
Molybdenum	CL-5	0.5	<=W	ug/g dry	4/1/99
Molybdenum	CL-6	0.5	<=W	ug/g dry	4/1/99
Molybdenum	CL-7	0.5	<=W	ug/g dry	4/1/99
Molybdenum	CL-8	0.5	<=W	ug/g dry	4/1/99
Molybdenum	ML-1	0.5	<=W	ug/g dry	4/1/99
Molybdenum	ML-10	0.5	<=W	ug/g dry	4/1/99
Molybdenum	ML-11	0.5	<=W	ug/g dry	4/1/99
Molybdenum	ML-12	0.5	<=W	ug/g dry	4/1/99
Molybdenum	ML-13	0.5	<=W	ug/g dry	4/1/99
Molybdenum	ML-14	0.5	<=W	ug/g dry	4/1/99
Molybdenum	ML-2	0.5	<=W	ug/g dry	4/1/99
Molybdenum	ML-3	2.5		ug/g dry	4/1/99
Molybdenum	ML-4	0.5	<=W	ug/g dry	4/1/99
Molybdenum	ML-5	0.5	<=W	ug/g dry	4/1/99
Molybdenum	ML-6	0.5	<=W	ug/g dry	4/1/99
Molybdenum	ML-7	0.5	<=W	ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Molybdenum	ML-8	0.5	<=W	ug/g dry	4/1/99
Molybdenum	ML-9	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-1	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-10	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-11	0.7	<T	ug/g dry	4/1/99
Molybdenum	MR-12	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-13	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-14	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-15	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-16	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-2	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-3	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-4	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-5	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-6	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-7	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-8	0.5	<=W	ug/g dry	4/1/99
Molybdenum	MR-9	0.5	<=W	ug/g dry	4/1/99
Molybdenum	RL-1	0.6	<T	ug/g dry	4/1/99
Molybdenum	RL-2	0.5	<=W	ug/g dry	4/1/99
Molybdenum	RL-3	0.5	<=W	ug/g dry	4/1/99
Molybdenum	RL-4	0.5	<=W	ug/g dry	4/1/99
Molybdenum	RL-5	0.6	<T	ug/g dry	4/1/99
Molybdenum	RL-6	0.5	<=W	ug/g dry	4/1/99
Molybdenum	RL-7	0.6	<T	ug/g dry	4/1/99
Molybdenum	SKR-1	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-1	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-10	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-11	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-12	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-13	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-14	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-15	0.7	<T	ug/g dry	4/1/99
Molybdenum	SL-2	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-3	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-4	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-5	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-6	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-7	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-8	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SL-9	0.6	<T	ug/g dry	4/1/99
Molybdenum	SR-1	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SR-2	0.5	<=W	ug/g dry	4/1/99
Molybdenum	SR-3	0.5	<=W	ug/g dry	4/1/99
Molybdenum	YC-1	5.4		ug/g dry	4/1/99
Nickel	BR-1	8.5		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Nickel	CL-1	1.3	<T	ug/g dry	4/1/99
Nickel	CL-2	5.9		ug/g dry	4/1/99
Nickel	CL-3	3.3		ug/g dry	4/1/99
Nickel	CL-4	1.7	<T	ug/g dry	4/1/99
Nickel	CL-5	0.9	<T	ug/g dry	4/1/99
Nickel	CL-6	1.6	<T	ug/g dry	4/1/99
Nickel	CL-7	1.4	<T	ug/g dry	4/1/99
Nickel	CL-8	11		ug/g dry	4/1/99
Nickel	ML-1	590		ug/g dry	4/1/99
Nickel	ML-10	22		ug/g dry	4/1/99
Nickel	ML-11	36		ug/g dry	4/1/99
Nickel	ML-12	83		ug/g dry	4/1/99
Nickel	ML-13	270		ug/g dry	4/1/99
Nickel	ML-14	36		ug/g dry	4/1/99
Nickel	ML-2	640		ug/g dry	4/1/99
Nickel	ML-3	460		ug/g dry	4/1/99
Nickel	ML-4	320		ug/g dry	4/1/99
Nickel	ML-5	260		ug/g dry	4/1/99
Nickel	ML-6	240		ug/g dry	4/1/99
Nickel	ML-7	100		ug/g dry	4/1/99
Nickel	ML-8	33		ug/g dry	4/1/99
Nickel	ML-9	72		ug/g dry	4/1/99
Nickel	MR-1	9.2		ug/g dry	4/1/99
Nickel	MR-10	470		ug/g dry	4/1/99
Nickel	MR-11	680		ug/g dry	4/1/99
Nickel	MR-12	24		ug/g dry	4/1/99
Nickel	MR-13	73		ug/g dry	4/1/99
Nickel	MR-14	34		ug/g dry	4/1/99
Nickel	MR-15	14		ug/g dry	4/1/99
Nickel	MR-16	26		ug/g dry	4/1/99
Nickel	MR-2	15		ug/g dry	4/1/99
Nickel	MR-3	13		ug/g dry	4/1/99
Nickel	MR-4	33		ug/g dry	4/1/99
Nickel	MR-5	77		ug/g dry	4/1/99
Nickel	MR-6	250		ug/g dry	4/1/99
Nickel	MR-7	550		ug/g dry	4/1/99
Nickel	MR-8	520		ug/g dry	4/1/99
Nickel	MR-9	440		ug/g dry	4/1/99
Nickel	RL-1	15		ug/g dry	4/1/99
Nickel	RL-2	24		ug/g dry	4/1/99
Nickel	RL-3	21		ug/g dry	4/1/99
Nickel	RL-4	4.8		ug/g dry	4/1/99
Nickel	RL-5	4.8		ug/g dry	4/1/99
Nickel	RL-6	5.1		ug/g dry	4/1/99
Nickel	RL-7	7.9		ug/g dry	4/1/99
Nickel	SKR-1	9.3		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Nickel	SL-1	41		ug/g dry	4/1/99
Nickel	SL-10	6.2		ug/g dry	4/1/99
Nickel	SL-11	5.8		ug/g dry	4/1/99
Nickel	SL-12	4.6		ug/g dry	4/1/99
Nickel	SL-13	4.9		ug/g dry	4/1/99
Nickel	SL-14	4.6		ug/g dry	4/1/99
Nickel	SL-15	5.8		ug/g dry	4/1/99
Nickel	SL-2	130		ug/g dry	4/1/99
Nickel	SL-3	37		ug/g dry	4/1/99
Nickel	SL-4	92		ug/g dry	4/1/99
Nickel	SL-5	63		ug/g dry	4/1/99
Nickel	SL-6	11		ug/g dry	4/1/99
Nickel	SL-7	16		ug/g dry	4/1/99
Nickel	SL-8	18		ug/g dry	4/1/99
Nickel	SL-9	31		ug/g dry	4/1/99
Nickel	SR-1	15		ug/g dry	4/1/99
Nickel	SR-2	17		ug/g dry	4/1/99
Nickel	SR-3	19		ug/g dry	4/1/99
Nickel	YC-1	1000		ug/g dry	4/1/99
NNTK	BR-1	1		mg/g dry	4/1/99
NNTK	CL-1	1.8		mg/g dry	4/1/99
NNTK	CL-2	4.5		mg/g dry	4/1/99
NNTK	CL-3	1.6		mg/g dry	4/1/99
NNTK	CL-4	1.8		mg/g dry	4/1/99
NNTK	CL-5	1.4		mg/g dry	4/1/99
NNTK	CL-6	0.8		mg/g dry	4/1/99
NNTK	CL-7	0.5		mg/g dry	4/1/99
NNTK	CL-8	6.7		mg/g dry	4/1/99
NNTK	ML-1	16		mg/g dry	4/1/99
NNTK	ML-10	0.5		mg/g dry	4/1/99
NNTK	ML-11	0.5		mg/g dry	4/1/99
NNTK	ML-12	5.8		mg/g dry	4/1/99
NNTK	ML-13	8.2		mg/g dry	4/1/99
NNTK	ML-14	2.2		mg/g dry	4/1/99
NNTK	ML-2	16		mg/g dry	4/1/99
NNTK	ML-3	18		mg/g dry	4/1/99
NNTK	ML-4	6.9		mg/g dry	4/1/99
NNTK	ML-5	6.1		mg/g dry	4/1/99
NNTK	ML-6	17		mg/g dry	4/1/99
NNTK	ML-7	7.4		mg/g dry	4/1/99
NNTK	ML-8	0.7		mg/g dry	4/1/99
NNTK	ML-9	5.7		mg/g dry	4/1/99
NNTK	MR-1	0.9		mg/g dry	4/1/99
NNTK	MR-10	8.1		mg/g dry	4/1/99
NNTK	MR-11	12		mg/g dry	4/1/99
NNTK	MR-12	2		mg/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
NNTK	MR-13	13		mg/g dry	4/1/99
NNTK	MR-14	2.8		mg/g dry	4/1/99
NNTK	MR-15	1.1		mg/g dry	4/1/99
NNTK	MR-16	6.6		mg/g dry	4/1/99
NNTK	MR-2	0.7		mg/g dry	4/1/99
NNTK	MR-3	1.8		mg/g dry	4/1/99
NNTK	MR-4	2		mg/g dry	4/1/99
NNTK	MR-5	2.1		mg/g dry	4/1/99
NNTK	MR-6	2.4		mg/g dry	4/1/99
NNTK	MR-7	1.4		mg/g dry	4/1/99
NNTK	MR-8	1.8		mg/g dry	4/1/99
NNTK	MR-9	5.5		mg/g dry	4/1/99
NNTK	RL-1	52		mg/g dry	4/1/99
NNTK	RL-2	53		mg/g dry	4/1/99
NNTK	RL-3	50		mg/g dry	4/1/99
NNTK	RL-4	3.2		mg/g dry	4/1/99
NNTK	RL-5	2.6		mg/g dry	4/1/99
NNTK	RL-6	1.2		mg/g dry	4/1/99
NNTK	RL-7	7.6		mg/g dry	4/1/99
NNTK	SKR-1	1.4		mg/g dry	4/1/99
NNTK	SL-1	4.6		mg/g dry	4/1/99
NNTK	SL-10	0.6		mg/g dry	4/1/99
NNTK	SL-11	0.4	<T	mg/g dry	4/1/99
NNTK	SL-12	0.3	<T	mg/g dry	4/1/99
NNTK	SL-13	0.4	<T	mg/g dry	4/1/99
NNTK	SL-14	0.6		mg/g dry	4/1/99
NNTK	SL-15	0.7		mg/g dry	4/1/99
NNTK	SL-2	7.5		mg/g dry	4/1/99
NNTK	SL-3	0.8		mg/g dry	4/1/99
NNTK	SL-4	9.5		mg/g dry	4/1/99
NNTK	SL-5	6.9		mg/g dry	4/1/99
NNTK	SL-6	0.6		mg/g dry	4/1/99
NNTK	SL-7	1.7		mg/g dry	4/1/99
NNTK	SL-8	2.9		mg/g dry	4/1/99
NNTK	SL-9	6.8		mg/g dry	4/1/99
NNTK	SR-1	8.4		mg/g dry	4/1/99
NNTK	SR-2	6.3		mg/g dry	4/1/99
NNTK	SR-3	3.8		mg/g dry	4/1/99
NNTK	YC-1	8.9		mg/g dry	4/1/99
Particles (0.17-2.63)	BR-1	3.5		%	4/1/99
Particles (0.17-2.63)	CL-1	22.9		%	4/1/99
Particles (0.17-2.63)	CL-2	23.3		%	4/1/99
Particles (0.17-2.63)	CL-3	13.6		%	4/1/99
Particles (0.17-2.63)	CL-4	12.6		%	4/1/99
Particles (0.17-2.63)	CL-5	12.6		%	4/1/99
Particles (0.17-2.63)	CL-6	4.2		%	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Particles (0.17-2.63)	CL-7	2.6		%	4/1/99
Particles (0.17-2.63)	CL-8	25		%	4/1/99
Particles (0.17-2.63)	ML-1	8.7		%	4/1/99
Particles (0.17-2.63)	ML-10	1.1		%	4/1/99
Particles (0.17-2.63)	ML-11	1.5		%	4/1/99
Particles (0.17-2.63)	ML-12	9.5		%	4/1/99
Particles (0.17-2.63)	ML-13	12.2		%	4/1/99
Particles (0.17-2.63)	ML-14	5.4		%	4/1/99
Particles (0.17-2.63)	ML-2	7.8		%	4/1/99
Particles (0.17-2.63)	ML-3	8.1		%	4/1/99
Particles (0.17-2.63)	ML-4	5.9		%	4/1/99
Particles (0.17-2.63)	ML-5	7.9		%	4/1/99
Particles (0.17-2.63)	ML-6	4.2		%	4/1/99
Particles (0.17-2.63)	ML-7	14.2		%	4/1/99
Particles (0.17-2.63)	ML-8	2.7		%	4/1/99
Particles (0.17-2.63)	ML-9	11.1		%	4/1/99
Particles (0.17-2.63)	MR-1	5		%	4/1/99
Particles (0.17-2.63)	MR-10	8.3		%	4/1/99
Particles (0.17-2.63)	MR-11	10		%	4/1/99
Particles (0.17-2.63)	MR-12	6.5		%	4/1/99
Particles (0.17-2.63)	MR-13	8.4		%	4/1/99
Particles (0.17-2.63)	MR-14	6.5		%	4/1/99
Particles (0.17-2.63)	MR-15	3.1		%	4/1/99
Particles (0.17-2.63)	MR-16	7.3		%	4/1/99
Particles (0.17-2.63)	MR-2	9.9		%	4/1/99
Particles (0.17-2.63)	MR-3	7.4		%	4/1/99
Particles (0.17-2.63)	MR-4	4.9		%	4/1/99
Particles (0.17-2.63)	MR-5	7.8		%	4/1/99
Particles (0.17-2.63)	MR-6	7.7		%	4/1/99
Particles (0.17-2.63)	MR-7	6.2		%	4/1/99
Particles (0.17-2.63)	MR-8	6.3		%	4/1/99
Particles (0.17-2.63)	MR-9	7.1		%	4/1/99
Particles (0.17-2.63)	RL-1	5.7		%	4/1/99
Particles (0.17-2.63)	RL-2	6.1		%	4/1/99
Particles (0.17-2.63)	RL-3	7.1		%	4/1/99
Particles (0.17-2.63)	RL-4	5.6		%	4/1/99
Particles (0.17-2.63)	RL-5	5.7		%	4/1/99
Particles (0.17-2.63)	RL-6	2.9		%	4/1/99
Particles (0.17-2.63)	RL-7	3.5		%	4/1/99
Particles (0.17-2.63)	SKR-1	6.4		%	4/1/99
Particles (0.17-2.63)	SL-1	9		%	4/1/99
Particles (0.17-2.63)	SL-10	0.9	<T	%	4/1/99
Particles (0.17-2.63)	SL-11	0.6	<T	%	4/1/99
Particles (0.17-2.63)	SL-12	0.8	<T	%	4/1/99
Particles (0.17-2.63)	SL-13	0.4	<T	%	4/1/99
Particles (0.17-2.63)	SL-14	1.4		%	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Particles (0.17-2.63)	SL-15	0.6	<T	%	4/1/99
Particles (0.17-2.63)	SL-2	14.6		%	4/1/99
Particles (0.17-2.63)	SL-3	7.9		%	4/1/99
Particles (0.17-2.63)	SL-4	15.2		%	4/1/99
Particles (0.17-2.63)	SL-5	13.6		%	4/1/99
Particles (0.17-2.63)	SL-6	1.9		%	4/1/99
Particles (0.17-2.63)	SL-7	5		%	4/1/99
Particles (0.17-2.63)	SL-8	5.9		%	4/1/99
Particles (0.17-2.63)	SL-9	6.8		%	4/1/99
Particles (0.17-2.63)	SR-1	7		%	4/1/99
Particles (0.17-2.63)	SR-2	8.6		%	4/1/99
Particles (0.17-2.63)	SR-3	14.2		%	4/1/99
Particles (0.17-2.63)	YC-1	11.3		%	4/1/99
Particles (2.63-62)	BR-1	21		%	4/1/99
Particles (2.63-62)	CL-1	62		%	4/1/99
Particles (2.63-62)	CL-2	66		%	4/1/99
Particles (2.63-62)	CL-3	43		%	4/1/99
Particles (2.63-62)	CL-4	47		%	4/1/99
Particles (2.63-62)	CL-5	40		%	4/1/99
Particles (2.63-62)	CL-6	16		%	4/1/99
Particles (2.63-62)	CL-7	10		%	4/1/99
Particles (2.63-62)	CL-8	69		%	4/1/99
Particles (2.63-62)	ML-1	69		%	4/1/99
Particles (2.63-62)	ML-10	8		%	4/1/99
Particles (2.63-62)	ML-11	10		%	4/1/99
Particles (2.63-62)	ML-12	67		%	4/1/99
Particles (2.63-62)	ML-13	69		%	4/1/99
Particles (2.63-62)	ML-14	31		%	4/1/99
Particles (2.63-62)	ML-2	67		%	4/1/99
Particles (2.63-62)	ML-3	66		%	4/1/99
Particles (2.63-62)	ML-4	52		%	4/1/99
Particles (2.63-62)	ML-5	55		%	4/1/99
Particles (2.63-62)	ML-6	43		%	4/1/99
Particles (2.63-62)	ML-7	63		%	4/1/99
Particles (2.63-62)	ML-8	21		%	4/1/99
Particles (2.63-62)	ML-9	64		%	4/1/99
Particles (2.63-62)	MR-1	29		%	4/1/99
Particles (2.63-62)	MR-10	54		%	4/1/99
Particles (2.63-62)	MR-11	67		%	4/1/99
Particles (2.63-62)	MR-12	40		%	4/1/99
Particles (2.63-62)	MR-13	57		%	4/1/99
Particles (2.63-62)	MR-14	34		%	4/1/99
Particles (2.63-62)	MR-15	22		%	4/1/99
Particles (2.63-62)	MR-16	44		%	4/1/99
Particles (2.63-62)	MR-2	29		%	4/1/99
Particles (2.63-62)	MR-3	43		%	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Particles (2.63-62)	MR-4	35		%	4/1/99
Particles (2.63-62)	MR-5	53		%	4/1/99
Particles (2.63-62)	MR-6	52		%	4/1/99
Particles (2.63-62)	MR-7	40		%	4/1/99
Particles (2.63-62)	MR-8	39		%	4/1/99
Particles (2.63-62)	MR-9	50		%	4/1/99
Particles (2.63-62)	RL-1	64		%	4/1/99
Particles (2.63-62)	RL-2	67		%	4/1/99
Particles (2.63-62)	RL-3	77		%	4/1/99
Particles (2.63-62)	RL-4	48		%	4/1/99
Particles (2.63-62)	RL-5	52		%	4/1/99
Particles (2.63-62)	RL-6	29		%	4/1/99
Particles (2.63-62)	RL-7	46		%	4/1/99
Particles (2.63-62)	SKR-1	35		%	4/1/99
Particles (2.63-62)	SL-1	55		%	4/1/99
Particles (2.63-62)	SL-10	7		%	4/1/99
Particles (2.63-62)	SL-11	5		%	4/1/99
Particles (2.63-62)	SL-12	6		%	4/1/99
Particles (2.63-62)	SL-13	3	<T	%	4/1/99
Particles (2.63-62)	SL-14	9		%	4/1/99
Particles (2.63-62)	SL-15	6		%	4/1/99
Particles (2.63-62)	SL-2	74		%	4/1/99
Particles (2.63-62)	SL-3	25		%	4/1/99
Particles (2.63-62)	SL-4	73		%	4/1/99
Particles (2.63-62)	SL-5	68		%	4/1/99
Particles (2.63-62)	SL-6	12		%	4/1/99
Particles (2.63-62)	SL-7	27		%	4/1/99
Particles (2.63-62)	SL-8	52		%	4/1/99
Particles (2.63-62)	SL-9	57		%	4/1/99
Particles (2.63-62)	SR-1	42		%	4/1/99
Particles (2.63-62)	SR-2	46		%	4/1/99
Particles (2.63-62)	SR-3	47		%	4/1/99
Particles (2.63-62)	YC-1	67		%	4/1/99
Particles (62-999))	BR-1	65		%	4/1/99
Particles (62-999))	CL-1	16		%	4/1/99
Particles (62-999))	CL-2	11		%	4/1/99
Particles (62-999))	CL-3	44		%	4/1/99
Particles (62-999))	CL-4	41		%	4/1/99
Particles (62-999))	CL-5	46		%	4/1/99
Particles (62-999))	CL-6	80		%	4/1/99
Particles (62-999))	CL-7	88		%	4/1/99
Particles (62-999))	CL-8	6		%	4/1/99
Particles (62-999))	ML-1	23		%	4/1/99
Particles (62-999))	ML-10	91		%	4/1/99
Particles (62-999))	ML-11	88		%	4/1/99
Particles (62-999))	ML-12	23		%	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Particles (62-999))	ML-13	18		%	4/1/99
Particles (62-999))	ML-14	56		%	4/1/99
Particles (62-999))	ML-2	26		%	4/1/99
Particles (62-999))	ML-3	26		%	4/1/99
Particles (62-999))	ML-4	42		%	4/1/99
Particles (62-999))	ML-5	37		%	4/1/99
Particles (62-999))	ML-6	45		%	4/1/99
Particles (62-999))	ML-7	23		%	4/1/99
Particles (62-999))	ML-8	77		%	4/1/99
Particles (62-999))	ML-9	25		%	4/1/99
Particles (62-999))	MR-1	66		%	4/1/99
Particles (62-999))	MR-10	38		%	4/1/99
Particles (62-999))	MR-11	23		%	4/1/99
Particles (62-999))	MR-12	54		%	4/1/99
Particles (62-999))	MR-13	34		%	4/1/99
Particles (62-999))	MR-14	48		%	4/1/99
Particles (62-999))	MR-15	75		%	4/1/99
Particles (62-999))	MR-16	43		%	4/1/99
Particles (62-999))	MR-2	56		%	4/1/99
Particles (62-999))	MR-3	49		%	4/1/99
Particles (62-999))	MR-4	59		%	4/1/99
Particles (62-999))	MR-5	39		%	4/1/99
Particles (62-999))	MR-6	38		%	4/1/99
Particles (62-999))	MR-7	54		%	4/1/99
Particles (62-999))	MR-8	55		%	4/1/99
Particles (62-999))	MR-9	43		%	4/1/99
Particles (62-999))	RL-1	30		%	4/1/99
Particles (62-999))	RL-2	27		%	4/1/99
Particles (62-999))	RL-3	16		%	4/1/99
Particles (62-999))	RL-4	46		%	4/1/99
Particles (62-999))	RL-5	43		%	4/1/99
Particles (62-999))	RL-6	67		%	4/1/99
Particles (62-999))	RL-7	45		%	4/1/99
Particles (62-999))	SKR-1	57		%	4/1/99
Particles (62-999))	SL-1	34		%	4/1/99
Particles (62-999))	SL-10	92		%	4/1/99
Particles (62-999))	SL-11	94		%	4/1/99
Particles (62-999))	SL-12	94		%	4/1/99
Particles (62-999))	SL-13	96		%	4/1/99
Particles (62-999))	SL-14	90		%	4/1/99
Particles (62-999))	SL-15	93		%	4/1/99
Particles (62-999))	SL-2	11		%	4/1/99
Particles (62-999))	SL-3	67		%	4/1/99
Particles (62-999))	SL-4	12		%	4/1/99
Particles (62-999))	SL-5	19		%	4/1/99
Particles (62-999))	SL-6	81		%	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Particles (62-999))	SL-7	68		%	4/1/99
Particles (62-999))	SL-8	42		%	4/1/99
Particles (62-999))	SL-9	36		%	4/1/99
Particles (62-999))	SR-1	40		%	4/1/99
Particles (62-999))	SR-2	35		%	4/1/99
Particles (62-999))	SR-3	39		%	4/1/99
Particles (62-999))	YC-1	22		%	4/1/99
Silver	BR-1		SQT	ug/g dry	4/1/99
Silver	CL-1		SQT	ug/g dry	4/1/99
Silver	CL-2		SQT	ug/g dry	4/1/99
Silver	CL-3		SQT	ug/g dry	4/1/99
Silver	CL-4		SQT	ug/g dry	4/1/99
Silver	CL-5		SQT	ug/g dry	4/1/99
Silver	CL-6		SQT	ug/g dry	4/1/99
Silver	CL-7		SQT	ug/g dry	4/1/99
Silver	CL-8	0.1	SQT	ug/g dry	4/1/99
Silver	ML-1	14	SQT	ug/g dry	4/1/99
Silver	ML-10		SQT	ug/g dry	4/1/99
Silver	ML-11	0.1	SQT	ug/g dry	4/1/99
Silver	ML-12	0.6	SQT	ug/g dry	4/1/99
Silver	ML-13	1.6	SQT	ug/g dry	4/1/99
Silver	ML-14	0.2	SQT	ug/g dry	4/1/99
Silver	ML-2	16	SQT	ug/g dry	4/1/99
Silver	ML-3	6.8	SQT	ug/g dry	4/1/99
Silver	ML-4	1.8	SQT	ug/g dry	4/1/99
Silver	ML-5	1.2	SQT	ug/g dry	4/1/99
Silver	ML-6	0.7	SQT	ug/g dry	4/1/99
Silver	ML-7	1.1	SQT	ug/g dry	4/1/99
Silver	ML-8	0.3	SQT	ug/g dry	4/1/99
Silver	ML-9	0.6	SQT	ug/g dry	4/1/99
Silver	MR-1		SQT	ug/g dry	4/1/99
Silver	MR-10	11	SQT	ug/g dry	4/1/99
Silver	MR-11	19	SQT	ug/g dry	4/1/99
Silver	MR-12		SQT	ug/g dry	4/1/99
Silver	MR-13	0.6	SQT	ug/g dry	4/1/99
Silver	MR-14	0.2	SQT	ug/g dry	4/1/99
Silver	MR-15		SQT	ug/g dry	4/1/99
Silver	MR-16	0.2	SQT	ug/g dry	4/1/99
Silver	MR-2		SQT	ug/g dry	4/1/99
Silver	MR-3		SQT	ug/g dry	4/1/99
Silver	MR-4	0.5	SQT	ug/g dry	4/1/99
Silver	MR-5	10	SQT	ug/g dry	4/1/99
Silver	MR-6	4.6	SQT	ug/g dry	4/1/99
Silver	MR-7	6.3	SQT	ug/g dry	4/1/99
Silver	MR-8	6.5	SQT	ug/g dry	4/1/99
Silver	MR-9	11	SQT	ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Silver	RL-1		SQT	ug/g dry	4/1/99
Silver	RL-2	0.4	SQT	ug/g dry	4/1/99
Silver	RL-3		SQT	ug/g dry	4/1/99
Silver	RL-4		SQT	ug/g dry	4/1/99
Silver	RL-5		SQT	ug/g dry	4/1/99
Silver	RL-6		SQT	ug/g dry	4/1/99
Silver	RL-7		SQT	ug/g dry	4/1/99
Silver	SKR-1	0.2	SQT	ug/g dry	4/1/99
Silver	SL-1	0.1	SQT	ug/g dry	4/1/99
Silver	SL-10	0.1	SQT	ug/g dry	4/1/99
Silver	SL-11		SQT	ug/g dry	4/1/99
Silver	SL-12		SQT	ug/g dry	4/1/99
Silver	SL-13		SQT	ug/g dry	4/1/99
Silver	SL-14		SQT	ug/g dry	4/1/99
Silver	SL-15		SQT	ug/g dry	4/1/99
Silver	SL-2	1	SQT	ug/g dry	4/1/99
Silver	SL-3	0.1	SQT	ug/g dry	4/1/99
Silver	SL-4	0.6	SQT	ug/g dry	4/1/99
Silver	SL-5	0.3	SQT	ug/g dry	4/1/99
Silver	SL-6		SQT	ug/g dry	4/1/99
Silver	SL-7		SQT	ug/g dry	4/1/99
Silver	SL-8		SQT	ug/g dry	4/1/99
Silver	SL-9	0.1	SQT	ug/g dry	4/1/99
Silver	SR-1	0.2	SQT	ug/g dry	4/1/99
Silver	SR-2	0.2	SQT	ug/g dry	4/1/99
Silver	SR-3	0.2	SQT	ug/g dry	4/1/99
Silver	YC-1	4	SQT	ug/g dry	4/1/99
Titanium	BR-1	710		ug/g dry	4/1/99
Titanium	CL-1	20	<=W	ug/g dry	4/1/99
Titanium	CL-2	130		ug/g dry	4/1/99
Titanium	CL-3	320		ug/g dry	4/1/99
Titanium	CL-4	150		ug/g dry	4/1/99
Titanium	CL-5	50	<T	ug/g dry	4/1/99
Titanium	CL-6	250		ug/g dry	4/1/99
Titanium	CL-7	380		ug/g dry	4/1/99
Titanium	CL-8	260		ug/g dry	4/1/99
Titanium	ML-1	470		ug/g dry	4/1/99
Titanium	ML-10	740		ug/g dry	4/1/99
Titanium	ML-11	670		ug/g dry	4/1/99
Titanium	ML-12	320		ug/g dry	4/1/99
Titanium	ML-13	120		ug/g dry	4/1/99
Titanium	ML-14	430		ug/g dry	4/1/99
Titanium	ML-2	640		ug/g dry	4/1/99
Titanium	ML-3	390		ug/g dry	4/1/99
Titanium	ML-4	470		ug/g dry	4/1/99
Titanium	ML-5	150		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Titanium	ML-6	210		ug/g dry	4/1/99
Titanium	ML-7	70	<T	ug/g dry	4/1/99
Titanium	ML-8	610		ug/g dry	4/1/99
Titanium	ML-9	930		ug/g dry	4/1/99
Titanium	MR-1	910		ug/g dry	4/1/99
Titanium	MR-10	710		ug/g dry	4/1/99
Titanium	MR-11	770		ug/g dry	4/1/99
Titanium	MR-12	820		ug/g dry	4/1/99
Titanium	MR-13	690		ug/g dry	4/1/99
Titanium	MR-14	600		ug/g dry	4/1/99
Titanium	MR-15	570		ug/g dry	4/1/99
Titanium	MR-16	550		ug/g dry	4/1/99
Titanium	MR-2	1100		ug/g dry	4/1/99
Titanium	MR-3	950		ug/g dry	4/1/99
Titanium	MR-4	930		ug/g dry	4/1/99
Titanium	MR-5	1200		ug/g dry	4/1/99
Titanium	MR-6	790		ug/g dry	4/1/99
Titanium	MR-7	970		ug/g dry	4/1/99
Titanium	MR-8	910		ug/g dry	4/1/99
Titanium	MR-9	860		ug/g dry	4/1/99
Titanium	RL-1	260		ug/g dry	4/1/99
Titanium	RL-2	340		ug/g dry	4/1/99
Titanium	RL-3	430		ug/g dry	4/1/99
Titanium	RL-4	570		ug/g dry	4/1/99
Titanium	RL-5	570		ug/g dry	4/1/99
Titanium	RL-6	420		ug/g dry	4/1/99
Titanium	RL-7	590		ug/g dry	4/1/99
Titanium	SKR-1	1000		ug/g dry	4/1/99
Titanium	SL-1	720		ug/g dry	4/1/99
Titanium	SL-10	1000		ug/g dry	4/1/99
Titanium	SL-11	1100		ug/g dry	4/1/99
Titanium	SL-12	1100		ug/g dry	4/1/99
Titanium	SL-13	780		ug/g dry	4/1/99
Titanium	SL-14	540		ug/g dry	4/1/99
Titanium	SL-15	840		ug/g dry	4/1/99
Titanium	SL-2	1200		ug/g dry	4/1/99
Titanium	SL-3	850		ug/g dry	4/1/99
Titanium	SL-4	1000		ug/g dry	4/1/99
Titanium	SL-5	1200		ug/g dry	4/1/99
Titanium	SL-6	610		ug/g dry	4/1/99
Titanium	SL-7	710		ug/g dry	4/1/99
Titanium	SL-8	960		ug/g dry	4/1/99
Titanium	SL-9	920		ug/g dry	4/1/99
Titanium	SR-1	740		ug/g dry	4/1/99
Titanium	SR-2	870		ug/g dry	4/1/99
Titanium	SR-3	1200		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Titanium	YC-1	640		ug/g dry	4/1/99
TOC	BR-1	33		mg/g dry	4/1/99
TOC	CL-1	24		mg/g dry	4/1/99
TOC	CL-2	66		mg/g dry	4/1/99
TOC	CL-3	21		mg/g dry	4/1/99
TOC	CL-4	23		mg/g dry	4/1/99
TOC	CL-5	20		mg/g dry	4/1/99
TOC	CL-6	18		mg/g dry	4/1/99
TOC	CL-7	5		mg/g dry	4/1/99
TOC	CL-8	72		mg/g dry	4/1/99
TOC	ML-1	200		mg/g dry	4/1/99
TOC	ML-10	6		mg/g dry	4/1/99
TOC	ML-11	11		mg/g dry	4/1/99
TOC	ML-12	70		mg/g dry	4/1/99
TOC	ML-13	89		mg/g dry	4/1/99
TOC	ML-14	21		mg/g dry	4/1/99
TOC	ML-2	200		mg/g dry	4/1/99
TOC	ML-3	170		mg/g dry	4/1/99
TOC	ML-4	63		mg/g dry	4/1/99
TOC	ML-5	66		mg/g dry	4/1/99
TOC	ML-6	230		mg/g dry	4/1/99
TOC	ML-7	89		mg/g dry	4/1/99
TOC	ML-8	10		mg/g dry	4/1/99
TOC	ML-9	80		mg/g dry	4/1/99
TOC	MR-1	8		mg/g dry	4/1/99
TOC	MR-10	140		mg/g dry	4/1/99
TOC	MR-11	140		mg/g dry	4/1/99
TOC	MR-12	33		mg/g dry	4/1/99
TOC	MR-13	140		mg/g dry	4/1/99
TOC	MR-14	38		mg/g dry	4/1/99
TOC	MR-15	17		mg/g dry	4/1/99
TOC	MR-16	120		mg/g dry	4/1/99
TOC	MR-2	13		mg/g dry	4/1/99
TOC	MR-3	30		mg/g dry	4/1/99
TOC	MR-4	39		mg/g dry	4/1/99
TOC	MR-5	32		mg/g dry	4/1/99
TOC	MR-6	32		mg/g dry	4/1/99
TOC	MR-7	38		mg/g dry	4/1/99
TOC	MR-8	26		mg/g dry	4/1/99
TOC	MR-9	120		mg/g dry	4/1/99
TOC	RL-1	270		mg/g dry	4/1/99
TOC	RL-2	220		mg/g dry	4/1/99
TOC	RL-3	210		mg/g dry	4/1/99
TOC	RL-4	37		mg/g dry	4/1/99
TOC	RL-5	37		mg/g dry	4/1/99
TOC	RL-6	32		mg/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
TOC	RL-7	160		mg/g dry	4/1/99
TOC	SKR-1	24		mg/g dry	4/1/99
TOC	SL-1	81		mg/g dry	4/1/99
TOC	SL-10	4	<T	mg/g dry	4/1/99
TOC	SL-11	14		mg/g dry	4/1/99
TOC	SL-12	7		mg/g dry	4/1/99
TOC	SL-13	2	<T	mg/g dry	4/1/99
TOC	SL-14	12		mg/g dry	4/1/99
TOC	SL-15	6		mg/g dry	4/1/99
TOC	SL-2	99		mg/g dry	4/1/99
TOC	SL-3	8		mg/g dry	4/1/99
TOC	SL-4	100		mg/g dry	4/1/99
TOC	SL-5	76		mg/g dry	4/1/99
TOC	SL-6	13		mg/g dry	4/1/99
TOC	SL-7	34		mg/g dry	4/1/99
TOC	SL-8	47		mg/g dry	4/1/99
TOC	SL-9	86		mg/g dry	4/1/99
TOC	SR-1	160		mg/g dry	4/1/99
TOC	SR-2	93		mg/g dry	4/1/99
TOC	SR-3	54		mg/g dry	4/1/99
TOC	YC-1	150		mg/g dry	4/1/99
TP	BR-1	0.52		mg/g dry	4/1/99
TP	CL-1	0.28		mg/g dry	4/1/99
TP	CL-2	0.76		mg/g dry	4/1/99
TP	CL-3	0.76		mg/g dry	4/1/99
TP	CL-4	0.42		mg/g dry	4/1/99
TP	CL-5	0.32		mg/g dry	4/1/99
TP	CL-6	0.58		mg/g dry	4/1/99
TP	CL-7	0.66		mg/g dry	4/1/99
TP	CL-8	1		mg/g dry	4/1/99
TP	ML-1	1.3		mg/g dry	4/1/99
TP	ML-10	0.52		mg/g dry	4/1/99
TP	ML-11	0.52		mg/g dry	4/1/99
TP	ML-12	0.76		mg/g dry	4/1/99
TP	ML-13	0.84		mg/g dry	4/1/99
TP	ML-14	0.8		mg/g dry	4/1/99
TP	ML-2	1.6		mg/g dry	4/1/99
TP	ML-3	1.2		mg/g dry	4/1/99
TP	ML-4	1.2		mg/g dry	4/1/99
TP	ML-5	1.4		mg/g dry	4/1/99
TP	ML-6	0.98		mg/g dry	4/1/99
TP	ML-7	0.78		mg/g dry	4/1/99
TP	ML-8	0.7		mg/g dry	4/1/99
TP	ML-9	1.2		mg/g dry	4/1/99
TP	MR-1	0.86		mg/g dry	4/1/99
TP	MR-10	1.1		mg/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
TP	MR-11	1.3		mg/g dry	4/1/99
TP	MR-12	0.76		mg/g dry	4/1/99
TP	MR-13	1.1		mg/g dry	4/1/99
TP	MR-14	0.68		mg/g dry	4/1/99
TP	MR-15	0.44		mg/g dry	4/1/99
TP	MR-16	1.2		mg/g dry	4/1/99
TP	MR-2	0.64		mg/g dry	4/1/99
TP	MR-3	0.96		mg/g dry	4/1/99
TP	MR-4	1.5		mg/g dry	4/1/99
TP	MR-5	1.2		mg/g dry	4/1/99
TP	MR-6	1.3		mg/g dry	4/1/99
TP	MR-7	1.4		mg/g dry	4/1/99
TP	MR-8	1.7		mg/g dry	4/1/99
TP	MR-9	1.1		mg/g dry	4/1/99
TP	RL-1	1.1		mg/g dry	4/1/99
TP	RL-2	1.8		mg/g dry	4/1/99
TP	RL-3	1.4		mg/g dry	4/1/99
TP	RL-4	0.74		mg/g dry	4/1/99
TP	RL-5	0.7		mg/g dry	4/1/99
TP	RL-6	0.68		mg/g dry	4/1/99
TP	RL-7	0.9		mg/g dry	4/1/99
TP	SKR-1	0.8		mg/g dry	4/1/99
TP	SL-1	1.2		mg/g dry	4/1/99
TP	SL-10	1.2		mg/g dry	4/1/99
TP	SL-11	0.6		mg/g dry	4/1/99
TP	SL-12	0.72		mg/g dry	4/1/99
TP	SL-13	0.48		mg/g dry	4/1/99
TP	SL-14	0.92		mg/g dry	4/1/99
TP	SL-15	0.6		mg/g dry	4/1/99
TP	SL-2	1.6		mg/g dry	4/1/99
TP	SL-3	1		mg/g dry	4/1/99
TP	SL-4	2.6		mg/g dry	4/1/99
TP	SL-5	1.5		mg/g dry	4/1/99
TP	SL-6	0.44		mg/g dry	4/1/99
TP	SL-7	0.6		mg/g dry	4/1/99
TP	SL-8	0.88		mg/g dry	4/1/99
TP	SL-9	1		mg/g dry	4/1/99
TP	SR-1	0.84		mg/g dry	4/1/99
TP	SR-2	0.86		mg/g dry	4/1/99
TP	SR-3	0.88		mg/g dry	4/1/99
TP	YC-1	2.1		mg/g dry	4/1/99
Uranium	BR-1	0.365	+/- 0.400	ug/g dry	4/1/99
Uranium	CL-1	0.15	+/- 0.410	ug/g dry	4/1/99
Uranium	CL-2	0.279	+/- 0.400	ug/g dry	4/1/99
Uranium	CL-3	0.266	+/- 0.410	ug/g dry	4/1/99
Uranium	CL-4	0.284	+/- 0.400	ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Uranium	CL-5	0.261	+/- 0.630	ug/g dry	4/1/99
Uranium	CL-6	0.981	+/- 0.410	ug/g dry	4/1/99
Uranium	CL-7	0.171	+/- 0.410	ug/g dry	4/1/99
Uranium	CL-8	0.91	+/- 0.650	ug/g dry	4/1/99
Uranium	ML-1	1.32	+/- 0.470	ug/g dry	4/1/99
Uranium	ML-10	0.182	+/- 0.400	ug/g dry	4/1/99
Uranium	ML-11	0.177	+/- 0.400	ug/g dry	4/1/99
Uranium	ML-12	0.662	+/- 0.400	ug/g dry	4/1/99
Uranium	ML-13	0.899	+/- 0.410	ug/g dry	4/1/99
Uranium	ML-14	0.289	+/- 0.400	ug/g dry	4/1/99
Uranium	ML-2	1.28	+/- 0.500	ug/g dry	4/1/99
Uranium	ML-3	3.44	+/- 0.510	ug/g dry	4/1/99
Uranium	ML-4	1.15	+/- 0.470	ug/g dry	4/1/99
Uranium	ML-5	2.11	+/- 0.500	ug/g dry	4/1/99
Uranium	ML-6	2.33	+/- 0.450	ug/g dry	4/1/99
Uranium	ML-7	0.792	+/- 0.410	ug/g dry	4/1/99
Uranium	ML-8	0.25	+/- 0.400	ug/g dry	4/1/99
Uranium	ML-9	0.542	+/- 0.400	ug/g dry	4/1/99
Uranium	MR-1	0.262	+/- 0.410	ug/g dry	4/1/99
Uranium	MR-10	0.889	+/- 0.440	ug/g dry	4/1/99
Uranium	MR-11	1.2	+/- 0.410	ug/g dry	4/1/99
Uranium	MR-12	1.03	+/- 0.420	ug/g dry	4/1/99
Uranium	MR-13	3.91	+/- 0.530	ug/g dry	4/1/99
Uranium	MR-14	1.7	+/- 0.440	ug/g dry	4/1/99
Uranium	MR-15	0.429	+/- 0.420	ug/g dry	4/1/99
Uranium	MR-16	0.508	+/- 0.420	ug/g dry	4/1/99
Uranium	MR-2	0.299	+/- 0.410	ug/g dry	4/1/99
Uranium	MR-3	0.389	+/- 0.410	ug/g dry	4/1/99
Uranium	MR-4	0.479	+/- 0.400	ug/g dry	4/1/99
Uranium	MR-5	0.475	+/- 0.410	ug/g dry	4/1/99
Uranium	MR-6	0.515	+/- 0.410	ug/g dry	4/1/99
Uranium	MR-7	0.544	+/- 0.420	ug/g dry	4/1/99
Uranium	MR-8	0.409	+/- 0.410	ug/g dry	4/1/99
Uranium	MR-9	0.886	+/- 0.430	ug/g dry	4/1/99
Uranium	RL-1	1.39	+/- 0.410	ug/g dry	4/1/99
Uranium	RL-2	1.51	+/- 0.440	ug/g dry	4/1/99
Uranium	RL-3	2.42	+/- 0.480	ug/g dry	4/1/99
Uranium	RL-4	0.17	+/- 0.400	ug/g dry	4/1/99
Uranium	RL-5	0.183	+/- 0.410	ug/g dry	4/1/99
Uranium	RL-6	0.23	+/- 0.420	ug/g dry	4/1/99
Uranium	RL-7	0.469	+/- 0.410	ug/g dry	4/1/99
Uranium	SKR-1	1.23	+/- 0.440	ug/g dry	4/1/99
Uranium	SL-1	1.56	+/- 0.410	ug/g dry	4/1/99
Uranium	SL-10	0.322	+/- 0.400	ug/g dry	4/1/99
Uranium	SL-11	0.287	+/- 0.400	ug/g dry	4/1/99
Uranium	SL-12	0.281	+/- 0.400	ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Uranium	SL-13	0.196	+/- 0.410	ug/g dry	4/1/99
Uranium	SL-14	0.339	+/- 0.400	ug/g dry	4/1/99
Uranium	SL-15	0.246	+/- 0.400	ug/g dry	4/1/99
Uranium	SL-2	3.77	+/- 0.440	ug/g dry	4/1/99
Uranium	SL-3	0.468	+/- 0.400	ug/g dry	4/1/99
Uranium	SL-4	3.26	+/- 0.440	ug/g dry	4/1/99
Uranium	SL-5	2.57	+/- 0.430	ug/g dry	4/1/99
Uranium	SL-6	0.673	+/- 0.400	ug/g dry	4/1/99
Uranium	SL-7	0.961	+/- 0.410	ug/g dry	4/1/99
Uranium	SL-8	1.51	+/- 0.410	ug/g dry	4/1/99
Uranium	SL-9	2.22	+/- 0.430	ug/g dry	4/1/99
Uranium	SR-1	3.01	+/- 0.600	ug/g dry	4/1/99
Uranium	SR-2	0.617	+/- 0.430	ug/g dry	4/1/99
Uranium	SR-3	0.548	+/- 0.410	ug/g dry	4/1/99
Uranium	YC-1	19	+/- 1.200	ug/g dry	4/1/99
Vanadium	BR-1	29		ug/g dry	4/1/99
Vanadium	CL-1	2	<T	ug/g dry	4/1/99
Vanadium	CL-2	11		ug/g dry	4/1/99
Vanadium	CL-3	12		ug/g dry	4/1/99
Vanadium	CL-4	5		ug/g dry	4/1/99
Vanadium	CL-5	3	<T	ug/g dry	4/1/99
Vanadium	CL-6	8		ug/g dry	4/1/99
Vanadium	CL-7	8		ug/g dry	4/1/99
Vanadium	CL-8	22		ug/g dry	4/1/99
Vanadium	ML-1	32		ug/g dry	4/1/99
Vanadium	ML-10	19		ug/g dry	4/1/99
Vanadium	ML-11	15		ug/g dry	4/1/99
Vanadium	ML-12	15		ug/g dry	4/1/99
Vanadium	ML-13	9		ug/g dry	4/1/99
Vanadium	ML-14	12		ug/g dry	4/1/99
Vanadium	ML-2	41		ug/g dry	4/1/99
Vanadium	ML-3	38		ug/g dry	4/1/99
Vanadium	ML-4	34		ug/g dry	4/1/99
Vanadium	ML-5	12		ug/g dry	4/1/99
Vanadium	ML-6	14		ug/g dry	4/1/99
Vanadium	ML-7	7		ug/g dry	4/1/99
Vanadium	ML-8	19		ug/g dry	4/1/99
Vanadium	ML-9	37		ug/g dry	4/1/99
Vanadium	MR-1	30		ug/g dry	4/1/99
Vanadium	MR-10	39		ug/g dry	4/1/99
Vanadium	MR-11	50		ug/g dry	4/1/99
Vanadium	MR-12	26		ug/g dry	4/1/99
Vanadium	MR-13	43		ug/g dry	4/1/99
Vanadium	MR-14	33		ug/g dry	4/1/99
Vanadium	MR-15	14		ug/g dry	4/1/99
Vanadium	MR-16	46		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Vanadium	MR-2	43		ug/g dry	4/1/99
Vanadium	MR-3	37		ug/g dry	4/1/99
Vanadium	MR-4	48		ug/g dry	4/1/99
Vanadium	MR-5	49		ug/g dry	4/1/99
Vanadium	MR-6	43		ug/g dry	4/1/99
Vanadium	MR-7	42		ug/g dry	4/1/99
Vanadium	MR-8	38		ug/g dry	4/1/99
Vanadium	MR-9	39		ug/g dry	4/1/99
Vanadium	RL-1	38		ug/g dry	4/1/99
Vanadium	RL-2	65		ug/g dry	4/1/99
Vanadium	RL-3	69		ug/g dry	4/1/99
Vanadium	RL-4	22		ug/g dry	4/1/99
Vanadium	RL-5	24		ug/g dry	4/1/99
Vanadium	RL-6	25		ug/g dry	4/1/99
Vanadium	RL-7	28		ug/g dry	4/1/99
Vanadium	SKR-1	27		ug/g dry	4/1/99
Vanadium	SL-1	36		ug/g dry	4/1/99
Vanadium	SL-10	18		ug/g dry	4/1/99
Vanadium	SL-11	15		ug/g dry	4/1/99
Vanadium	SL-12	23		ug/g dry	4/1/99
Vanadium	SL-13	14		ug/g dry	4/1/99
Vanadium	SL-14	18		ug/g dry	4/1/99
Vanadium	SL-15	14		ug/g dry	4/1/99
Vanadium	SL-2	65		ug/g dry	4/1/99
Vanadium	SL-3	21		ug/g dry	4/1/99
Vanadium	SL-4	66		ug/g dry	4/1/99
Vanadium	SL-5	62		ug/g dry	4/1/99
Vanadium	SL-6	21		ug/g dry	4/1/99
Vanadium	SL-7	27		ug/g dry	4/1/99
Vanadium	SL-8	26		ug/g dry	4/1/99
Vanadium	SL-9	33		ug/g dry	4/1/99
Vanadium	SR-1	33		ug/g dry	4/1/99
Vanadium	SR-2	47		ug/g dry	4/1/99
Vanadium	SR-3	52		ug/g dry	4/1/99
Vanadium	YC-1	44		ug/g dry	4/1/99
Zinc	BR-1	65		ug/g dry	4/1/99
Zinc	CL-1	12	<T	ug/g dry	4/1/99
Zinc	CL-2	57		ug/g dry	4/1/99
Zinc	CL-3	38		ug/g dry	4/1/99
Zinc	CL-4	16	<T	ug/g dry	4/1/99
Zinc	CL-5	11	<T	ug/g dry	4/1/99
Zinc	CL-6	12	<T	ug/g dry	4/1/99
Zinc	CL-7	10	<T	ug/g dry	4/1/99
Zinc	CL-8	89		ug/g dry	4/1/99
Zinc	ML-1	360		ug/g dry	4/1/99
Zinc	ML-10	22	<T	ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Zinc	ML-11	21	<T	ug/g dry	4/1/99
Zinc	ML-12	78		ug/g dry	4/1/99
Zinc	ML-13	80		ug/g dry	4/1/99
Zinc	ML-14	31		ug/g dry	4/1/99
Zinc	ML-2	330		ug/g dry	4/1/99
Zinc	ML-3	240		ug/g dry	4/1/99
Zinc	ML-4	130		ug/g dry	4/1/99
Zinc	ML-5	100		ug/g dry	4/1/99
Zinc	ML-6	310		ug/g dry	4/1/99
Zinc	ML-7	110		ug/g dry	4/1/99
Zinc	ML-8	30		ug/g dry	4/1/99
Zinc	ML-9	89		ug/g dry	4/1/99
Zinc	MR-1	56		ug/g dry	4/1/99
Zinc	MR-10	200		ug/g dry	4/1/99
Zinc	MR-11	270		ug/g dry	4/1/99
Zinc	MR-12	81		ug/g dry	4/1/99
Zinc	MR-13	370		ug/g dry	4/1/99
Zinc	MR-14	170		ug/g dry	4/1/99
Zinc	MR-15	86		ug/g dry	4/1/99
Zinc	MR-16	210		ug/g dry	4/1/99
Zinc	MR-2	46		ug/g dry	4/1/99
Zinc	MR-3	87		ug/g dry	4/1/99
Zinc	MR-4	100		ug/g dry	4/1/99
Zinc	MR-5	120		ug/g dry	4/1/99
Zinc	MR-6	130		ug/g dry	4/1/99
Zinc	MR-7	130		ug/g dry	4/1/99
Zinc	MR-8	120		ug/g dry	4/1/99
Zinc	MR-9	160		ug/g dry	4/1/99
Zinc	RL-1	210		ug/g dry	4/1/99
Zinc	RL-2	300		ug/g dry	4/1/99
Zinc	RL-3	170		ug/g dry	4/1/99
Zinc	RL-4	33		ug/g dry	4/1/99
Zinc	RL-5	45		ug/g dry	4/1/99
Zinc	RL-6	32		ug/g dry	4/1/99
Zinc	RL-7	86		ug/g dry	4/1/99
Zinc	SKR-1	60		ug/g dry	4/1/99
Zinc	SL-1	150		ug/g dry	4/1/99
Zinc	SL-10	22	<T	ug/g dry	4/1/99
Zinc	SL-11	21	<T	ug/g dry	4/1/99
Zinc	SL-12	22	<T	ug/g dry	4/1/99
Zinc	SL-13	32		ug/g dry	4/1/99
Zinc	SL-14	23	<T	ug/g dry	4/1/99
Zinc	SL-15	40		ug/g dry	4/1/99
Zinc	SL-2	510		ug/g dry	4/1/99
Zinc	SL-3	340		ug/g dry	4/1/99
Zinc	SL-4	460		ug/g dry	4/1/99

Parameter	Golder Station	Result	Remark	Units	Date
Zinc	SL-5	610		ug/g dry	4/1/99
Zinc	SL-6	47		ug/g dry	4/1/99
Zinc	SL-7	120		ug/g dry	4/1/99
Zinc	SL-8	71		ug/g dry	4/1/99
Zinc	SL-9	120		ug/g dry	4/1/99
Zinc	SR-1	92		ug/g dry	4/1/99
Zinc	SR-2	99		ug/g dry	4/1/99
Zinc	SR-3	120		ug/g dry	4/1/99
Zinc	YC-1	210		ug/g dry	4/1/99

Appendix II.5 Sediment Core Data

Sediment Core Data

Station	Parameter	Date	Description	Result	Units	Remark
MR-7	As	19-Sep-99	Exchangeable Metals	4.1	ppm	000
MR-7	As	19-Sep-99	Metals Bound to Carbonates	24.7	ppm	000
MR-7	As	19-Sep-99	Metals Bound to Iron and Manganese	50	ppm	000
MR-7	As	19-Sep-99	Metals Bound to Organic Matter	92.5	ppm	000
MR-7	As	19-Sep-99	Residual Metals	2310	ppm	000
MR-7	As	25-Aug-99	Sediment Samples	937	ppm	000
MR-7	As	25-Aug-99	Sediment Samples	1040	ppm	000
MR-7	As	25-Aug-99	Sediment Samples	2160	ppm	000
MR-7	Co	19-Sep-99	Exchangeable Metals	2.1	ppm	000
MR-7	Co	19-Sep-99	Metals Bound to Carbonates	16.7	ppm	000
MR-7	Co	19-Sep-99	Metals Bound to Iron and Manganese	176	ppm	000
MR-7	Co	19-Sep-99	Metals Bound to Organic Matter	19.5	ppm	000
MR-7	Co	19-Sep-99	Residual Metals	99	ppm	000
MR-7	Co	25-Aug-99	Sediment Samples	332	ppm	000
MR-7	Co	25-Aug-99	Sediment Samples	393	ppm	000
MR-7	Co	25-Aug-99	Sediment Samples	622	ppm	000
MR-7	Cu	19-Sep-99	Exchangeable Metals	0.3	ppm	000
MR-7	Cu	19-Sep-99	Metals Bound to Carbonates	2.9	ppm	000
MR-7	Cu	19-Sep-99	Metals Bound to Iron and Manganese	8.4	ppm	000
MR-7	Cu	19-Sep-99	Metals Bound to Organic Matter	25.6	ppm	000
MR-7	Cu	19-Sep-99	Residual Metals	15	ppm	000
MR-7	Cu	25-Aug-99	Sediment Samples	75	ppm	000
MR-7	Cu	25-Aug-99	Sediment Samples	109	ppm	000
MR-7	Cu	25-Aug-99	Sediment Samples	159	ppm	000
MR-7	Ni	19-Sep-99	Exchangeable Metals	2	ppm	<=W
MR-7	Ni	19-Sep-99	Metals Bound to Carbonates	8	ppm	000
MR-7	Ni	19-Sep-99	Metals Bound to Iron and Manganese	173	ppm	000
MR-7	Ni	19-Sep-99	Metals Bound to Organic Matter	19	ppm	000
MR-7	Ni	19-Sep-99	Residual Metals	111	ppm	000
MR-7	Ni	25-Aug-99	Sediment Samples	400	ppm	000
MR-7	Ni	25-Aug-99	Sediment Samples	489	ppm	000
MR-7	Ni	25-Aug-99	Sediment Samples	918	ppm	000
MR-7	Pb	19-Sep-99	Exchangeable Metals	4	ppm	<=W
MR-7	Pb	19-Sep-99	Metals Bound to Carbonates	4	ppm	000
MR-7	Pb	19-Sep-99	Metals Bound to Iron and Manganese	7	ppm	000
MR-7	Pb	19-Sep-99	Metals Bound to Organic Matter	5	ppm	<=W
MR-7	Pb	19-Sep-99	Residual Metals	12	ppm	000
MR-7	Pb	25-Aug-99	Sediment Samples	25	ppm	000
MR-7	Pb	25-Aug-99	Sediment Samples	36	ppm	000
MR-7	Pb	25-Aug-99	Sediment Samples	57	ppm	000
MR-7	Hg	19-Sep-99	Exchangeable Metals	0.01	ppm	<=W
MR-7	Hg	19-Sep-99	Metals Bound to Carbonates	0.01	ppm	<=W
MR-7	Hg	19-Sep-99	Metals Bound to Iron and Manganese	0.04	ppm	000
MR-7	Hg	19-Sep-99	Metals Bound to Organic Matter	0.06	ppm	000
MR-7	Hg	19-Sep-99	Residual Metals	1.33	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-7	Hg	25-Aug-99	Sediment Samples	1.32	ppm	000
MR-7	Hg	25-Aug-99	Sediment Samples	1.46	ppm	000
MR-7	Hg	25-Aug-99	Sediment Samples	2.22	ppm	000
MR-7	U	19-Sep-99	Exchangeable Metals	0.1	ppm	<=W
MR-7	U	19-Sep-99	Metals Bound to Carbonates	0.1	ppm	000
MR-7	U	19-Sep-99	Metals Bound to Iron and Manganese	0.2	ppm	<=W
MR-7	U	19-Sep-99	Metals Bound to Organic Matter	0.2	ppm	<=W
MR-7	U	19-Sep-99	Residual Metals	1.3	ppm	000
MR-7	U	25-Aug-99	Sediment Samples	0.55	ppm	000
MR-7	U	25-Aug-99	Sediment Samples	0.78	ppm	000
MR-7	U	25-Aug-99	Sediment Samples	0.7	ppm	000
MR-7	Ag	19-Sep-99	Exchangeable Metals	0.3	ppm	<=W
MR-7	Ag	19-Sep-99	Metals Bound to Carbonates	0.3	ppm	<=W
MR-7	Ag	19-Sep-99	Metals Bound to Iron and Manganese	1.9	ppm	000
MR-7	Ag	19-Sep-99	Metals Bound to Organic Matter	1	ppm	000
MR-7	Ag	19-Sep-99	Residual Metals	0.2	ppm	000
MR-7	Ag	25-Aug-99	Sediment Samples	1.6	ppm	000
MR-7	Ag	25-Aug-99	Sediment Samples	1.2	ppm	000
MR-7	Ag	25-Aug-99	Sediment Samples	2.8	ppm	000
MR-7	Al	19-Sep-99	Exchangeable Metals	3	ppm	<=W
MR-7	Al	19-Sep-99	Metals Bound to Carbonates	36	ppm	000
MR-7	Al	19-Sep-99	Metals Bound to Iron and Manganese	725	ppm	000
MR-7	Al	19-Sep-99	Metals Bound to Organic Matter	665	ppm	000
MR-7	Al	19-Sep-99	Residual Metals	41400	ppm	000
MR-7	Al	25-Aug-99	Sediment Samples	7450	ppm	000
MR-7	Al	25-Aug-99	Sediment Samples	7070	ppm	000
MR-7	Al	25-Aug-99	Sediment Samples	7940	ppm	000
MR-7	Ba	19-Sep-99	Exchangeable Metals	31.3	ppm	000
MR-7	Ba	19-Sep-99	Metals Bound to Carbonates	22.5	ppm	000
MR-7	Ba	19-Sep-99	Metals Bound to Iron and Manganese	27.8	ppm	000
MR-7	Ba	19-Sep-99	Metals Bound to Organic Matter	5.5	ppm	000
MR-7	Ba	19-Sep-99	Residual Metals	583	ppm	000
MR-7	Ba	25-Aug-99	Sediment Samples	123	ppm	000
MR-7	Ba	25-Aug-99	Sediment Samples	115	ppm	000
MR-7	Ba	25-Aug-99	Sediment Samples	123	ppm	000
MR-7	Be	19-Sep-99	Exchangeable Metals	0.04	ppm	<=W
MR-7	Be	19-Sep-99	Metals Bound to Carbonates	0.04	ppm	<=W
MR-7	Be	19-Sep-99	Metals Bound to Iron and Manganese	0.11	ppm	000
MR-7	Be	19-Sep-99	Metals Bound to Organic Matter	0.05	ppm	<=W
MR-7	Be	19-Sep-99	Residual Metals	1.23	ppm	000
MR-7	Be	25-Aug-99	Sediment Samples	0.4	ppm	000
MR-7	Be	25-Aug-99	Sediment Samples	0.4	ppm	000
MR-7	Be	25-Aug-99	Sediment Samples	0.4	ppm	000
MR-7	Bi	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-7	Bi	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
MR-7	Bi	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
MR-7	Bi	19-Sep-99	Metals Bound to Organic Matter	10	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-7	Bi	19-Sep-99	Residual Metals	0	ppm	ND
MR-7	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
MR-7	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
MR-7	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
MR-7	Ca	19-Sep-99	Exchangeable Metals	1560	ppm	000
MR-7	Ca	19-Sep-99	Metals Bound to Carbonates	554	ppm	000
MR-7	Ca	19-Sep-99	Metals Bound to Iron and Manganese	917	ppm	000
MR-7	Ca	19-Sep-99	Metals Bound to Organic Matter	298	ppm	000
MR-7	Ca	19-Sep-99	Residual Metals	25200	ppm	000
MR-7	Ca	25-Aug-99	Sediment Samples	5670	ppm	000
MR-7	Ca	25-Aug-99	Sediment Samples	5660	ppm	000
MR-7	Ca	25-Aug-99	Sediment Samples	6190	ppm	000
MR-7	Cd	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-7	Cd	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
MR-7	Cd	19-Sep-99	Metals Bound to Iron and Manganese	0.5	ppm	<=W
MR-7	Cd	19-Sep-99	Metals Bound to Organic Matter	0.5	ppm	<=W
MR-7	Cd	19-Sep-99	Residual Metals	0.1	ppm	<=W
MR-7	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
MR-7	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
MR-7	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
MR-7	Cr	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-7	Cr	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
MR-7	Cr	19-Sep-99	Metals Bound to Iron and Manganese	4.1	ppm	000
MR-7	Cr	19-Sep-99	Metals Bound to Organic Matter	3.8	ppm	000
MR-7	Cr	19-Sep-99	Residual Metals	104	ppm	000
MR-7	Cr	25-Aug-99	Sediment Samples	45	ppm	000
MR-7	Cr	25-Aug-99	Sediment Samples	50	ppm	000
MR-7	Cr	25-Aug-99	Sediment Samples	74	ppm	000
MR-7	Fe	19-Sep-99	Exchangeable Metals	3	ppm	000
MR-7	Fe	19-Sep-99	Metals Bound to Carbonates	334	ppm	000
MR-7	Fe	19-Sep-99	Metals Bound to Iron and Manganese	5440	ppm	000
MR-7	Fe	19-Sep-99	Metals Bound to Organic Matter	317	ppm	000
MR-7	Fe	19-Sep-99	Residual Metals	31800	ppm	000
MR-7	Fe	25-Aug-99	Sediment Samples	22300	ppm	000
MR-7	Fe	25-Aug-99	Sediment Samples	22000	ppm	000
MR-7	Fe	25-Aug-99	Sediment Samples	23800	ppm	000
MR-7	K	19-Sep-99	Exchangeable Metals	109	ppm	000
MR-7	K	19-Sep-99	Metals Bound to Carbonates	80	ppm	<=W
MR-7	K	19-Sep-99	Metals Bound to Iron and Manganese	100	ppm	<=W
MR-7	K	19-Sep-99	Metals Bound to Organic Matter	100	ppm	<=W
MR-7	K	19-Sep-99	Residual Metals	15000	ppm	000
MR-7	K	25-Aug-99	Sediment Samples	644	ppm	000
MR-7	K	25-Aug-99	Sediment Samples	631	ppm	000
MR-7	K	25-Aug-99	Sediment Samples	847	ppm	000
MR-7	Mg	19-Sep-99	Exchangeable Metals	67	ppm	000
MR-7	Mg	19-Sep-99	Metals Bound to Carbonates	25	ppm	000
MR-7	Mg	19-Sep-99	Metals Bound to Iron and Manganese	764	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-7	Mg	19-Sep-99	Metals Bound to Organic Matter	405	ppm	000
MR-7	Mg	19-Sep-99	Residual Metals	11300	ppm	000
MR-7	Mg	25-Aug-99	Sediment Samples	5860	ppm	000
MR-7	Mg	25-Aug-99	Sediment Samples	5940	ppm	000
MR-7	Mg	25-Aug-99	Sediment Samples	6500	ppm	000
MR-7	Mn	19-Sep-99	Exchangeable Metals	79	ppm	000
MR-7	Mn	19-Sep-99	Metals Bound to Carbonates	66.9	ppm	000
MR-7	Mn	19-Sep-99	Metals Bound to Iron and Manganese	119	ppm	000
MR-7	Mn	19-Sep-99	Metals Bound to Organic Matter	10.1	ppm	000
MR-7	Mn	19-Sep-99	Residual Metals	407	ppm	000
MR-7	Mn	25-Aug-99	Sediment Samples	210	ppm	000
MR-7	Mn	25-Aug-99	Sediment Samples	201	ppm	000
MR-7	Mn	25-Aug-99	Sediment Samples	239	ppm	000
MR-7	Mo	19-Sep-99	Exchangeable Metals	2	ppm	<=W
MR-7	Mo	19-Sep-99	Metals Bound to Carbonates	1	ppm	<=W
MR-7	Mo	19-Sep-99	Metals Bound to Iron and Manganese	2	ppm	<=W
MR-7	Mo	19-Sep-99	Metals Bound to Organic Matter	2	ppm	<=W
MR-7	Mo	19-Sep-99	Residual Metals	5	ppm	<=W
MR-7	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
MR-7	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
MR-7	Mo	25-Aug-99	Sediment Samples	3	ppm	000
MR-7	Na	19-Sep-99	Exchangeable Metals	0	ppm	ND
MR-7	Na	19-Sep-99	Metals Bound to Carbonates	0	ppm	ND
MR-7	Na	19-Sep-99	Metals Bound to Iron and Manganese	0	ppm	ND
MR-7	Na	19-Sep-99	Metals Bound to Organic Matter	0	ppm	ND
MR-7	Na	19-Sep-99	Residual Metals	0	ppm	ND
MR-7	Na	25-Aug-99	Sediment Samples	133	ppm	000
MR-7	Na	25-Aug-99	Sediment Samples	119	ppm	000
MR-7	Na	25-Aug-99	Sediment Samples	132	ppm	000
MR-7	P	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-7	P	19-Sep-99	Metals Bound to Carbonates	14	ppm	000
MR-7	P	19-Sep-99	Metals Bound to Iron and Manganese	42	ppm	000
MR-7	P	19-Sep-99	Metals Bound to Organic Matter	31	ppm	000
MR-7	P	19-Sep-99	Residual Metals	1310	ppm	000
MR-7	P	25-Aug-99	Sediment Samples	1310	ppm	000
MR-7	P	25-Aug-99	Sediment Samples	1360	ppm	000
MR-7	P	25-Aug-99	Sediment Samples	1260	ppm	000
MR-7	S	19-Sep-99	Exchangeable Metals	127	ppm	000
MR-7	S	19-Sep-99	Metals Bound to Carbonates	18	ppm	000
MR-7	S	19-Sep-99	Metals Bound to Iron and Manganese	150	ppm	000
MR-7	S	19-Sep-99	Metals Bound to Organic Matter	1280	ppm	000
MR-7	S	19-Sep-99	Residual Metals	0	ppm	ND
MR-7	S	25-Aug-99	Sediment Samples	0	ppm	ND
MR-7	S	25-Aug-99	Sediment Samples	0	ppm	ND
MR-7	S	25-Aug-99	Sediment Samples	0	ppm	ND
MR-7	Sb	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-7	Sb	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W

Station	Parameter	Date	Description	Result	Units	Remark
MR-7	Sb	19-Sep-99	Metals Bound to Iron and Manganese	39	ppm	000
MR-7	Sb	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
MR-7	Sb	19-Sep-99	Residual Metals	0	ppm	ND
MR-7	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
MR-7	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
MR-7	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
MR-7	Se	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-7	Se	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
MR-7	Se	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
MR-7	Se	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
MR-7	Se	19-Sep-99	Residual Metals	0	ppm	ND
MR-7	Se	25-Aug-99	Sediment Samples	0	ppm	ND
MR-7	Se	25-Aug-99	Sediment Samples	0	ppm	ND
MR-7	Se	25-Aug-99	Sediment Samples	0	ppm	ND
MR-7	Sr	19-Sep-99	Exchangeable Metals	6.4	ppm	000
MR-7	Sr	19-Sep-99	Metals Bound to Carbonates	2.2	ppm	000
MR-7	Sr	19-Sep-99	Metals Bound to Iron and Manganese	2.4	ppm	000
MR-7	Sr	19-Sep-99	Metals Bound to Organic Matter	1.3	ppm	000
MR-7	Sr	19-Sep-99	Residual Metals	289	ppm	000
MR-7	Sr	25-Aug-99	Sediment Samples	24.6	ppm	000
MR-7	Sr	25-Aug-99	Sediment Samples	23.9	ppm	000
MR-7	Sr	25-Aug-99	Sediment Samples	22.5	ppm	000
MR-7	Ti	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-7	Ti	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
MR-7	Ti	19-Sep-99	Metals Bound to Iron and Manganese	0.9	ppm	000
MR-7	Ti	19-Sep-99	Metals Bound to Organic Matter	2.6	ppm	000
MR-7	Ti	19-Sep-99	Residual Metals	4530	ppm	000
MR-7	Ti	25-Aug-99	Sediment Samples	239	ppm	000
MR-7	Ti	25-Aug-99	Sediment Samples	286	ppm	000
MR-7	Ti	25-Aug-99	Sediment Samples	259	ppm	000
MR-7	V	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-7	V	19-Sep-99	Metals Bound to Carbonates	0.8	ppm	000
MR-7	V	19-Sep-99	Metals Bound to Iron and Manganese	3.7	ppm	000
MR-7	V	19-Sep-99	Metals Bound to Organic Matter	1.1	ppm	000
MR-7	V	19-Sep-99	Residual Metals	76	ppm	000
MR-7	V	25-Aug-99	Sediment Samples	25	ppm	000
MR-7	V	25-Aug-99	Sediment Samples	25	ppm	000
MR-7	V	25-Aug-99	Sediment Samples	27	ppm	000
MR-7	Zn	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-7	Zn	19-Sep-99	Metals Bound to Carbonates	4.8	ppm	000
MR-7	Zn	19-Sep-99	Metals Bound to Iron and Manganese	42.1	ppm	000
MR-7	Zn	19-Sep-99	Metals Bound to Organic Matter	7.6	ppm	000
MR-7	Zn	19-Sep-99	Residual Metals	56	ppm	000
MR-7	Zn	25-Aug-99	Sediment Samples	92	ppm	000
MR-7	Zn	25-Aug-99	Sediment Samples	91	ppm	000
MR-7	Zn	25-Aug-99	Sediment Samples	120	ppm	000
MR-8	As	19-Sep-99	Exchangeable Metals	4.4	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-8	As	19-Sep-99	Metals Bound to Carbonates	33.6	ppm	000
MR-8	As	19-Sep-99	Metals Bound to Iron and Manganese	73	ppm	000
MR-8	As	19-Sep-99	Metals Bound to Organic Matter	23	ppm	000
MR-8	As	19-Sep-99	Residual Metals	723	ppm	000
MR-8	As	25-Aug-99	Sediment Samples	531	ppm	000
MR-8	As	25-Aug-99	Sediment Samples	626	ppm	000
MR-8	As	25-Aug-99	Sediment Samples	922	ppm	000
MR-8	Co	19-Sep-99	Exchangeable Metals	2.7	ppm	000
MR-8	Co	19-Sep-99	Metals Bound to Carbonates	13.4	ppm	000
MR-8	Co	19-Sep-99	Metals Bound to Iron and Manganese	57.8	ppm	000
MR-8	Co	19-Sep-99	Metals Bound to Organic Matter	25.7	ppm	000
MR-8	Co	19-Sep-99	Residual Metals	66	ppm	000
MR-8	Co	25-Aug-99	Sediment Samples	202	ppm	000
MR-8	Co	25-Aug-99	Sediment Samples	238	ppm	000
MR-8	Co	25-Aug-99	Sediment Samples	256	ppm	000
MR-8	Cu	19-Sep-99	Exchangeable Metals	0.4	ppm	000
MR-8	Cu	19-Sep-99	Metals Bound to Carbonates	3.5	ppm	000
MR-8	Cu	19-Sep-99	Metals Bound to Iron and Manganese	2.6	ppm	000
MR-8	Cu	19-Sep-99	Metals Bound to Organic Matter	23.4	ppm	000
MR-8	Cu	19-Sep-99	Residual Metals	25.1	ppm	000
MR-8	Cu	25-Aug-99	Sediment Samples	48	ppm	000
MR-8	Cu	25-Aug-99	Sediment Samples	63	ppm	000
MR-8	Cu	25-Aug-99	Sediment Samples	69	ppm	000
MR-8	Ni	19-Sep-99	Exchangeable Metals	2	ppm	<=W
MR-8	Ni	19-Sep-99	Metals Bound to Carbonates	6	ppm	000
MR-8	Ni	19-Sep-99	Metals Bound to Iron and Manganese	58	ppm	000
MR-8	Ni	19-Sep-99	Metals Bound to Organic Matter	33	ppm	000
MR-8	Ni	19-Sep-99	Residual Metals	87	ppm	000
MR-8	Ni	25-Aug-99	Sediment Samples	222	ppm	000
MR-8	Ni	25-Aug-99	Sediment Samples	278	ppm	000
MR-8	Ni	25-Aug-99	Sediment Samples	306	ppm	000
MR-8	Pb	19-Sep-99	Exchangeable Metals	4	ppm	<=W
MR-8	Pb	19-Sep-99	Metals Bound to Carbonates	4	ppm	<=W
MR-8	Pb	19-Sep-99	Metals Bound to Iron and Manganese	5	ppm	<=W
MR-8	Pb	19-Sep-99	Metals Bound to Organic Matter	5	ppm	<=W
MR-8	Pb	19-Sep-99	Residual Metals	18	ppm	000
MR-8	Pb	25-Aug-99	Sediment Samples	14	ppm	000
MR-8	Pb	25-Aug-99	Sediment Samples	16	ppm	000
MR-8	Pb	25-Aug-99	Sediment Samples	17	ppm	000
MR-8	Hg	19-Sep-99	Exchangeable Metals	0.01	ppm	<=W
MR-8	Hg	19-Sep-99	Metals Bound to Carbonates	0.01	ppm	<=W
MR-8	Hg	19-Sep-99	Metals Bound to Iron and Manganese	0.02	ppm	<=W
MR-8	Hg	19-Sep-99	Metals Bound to Organic Matter	0.04	ppm	000
MR-8	Hg	19-Sep-99	Residual Metals	1.08	ppm	000
MR-8	Hg	25-Aug-99	Sediment Samples	1.07	ppm	000
MR-8	Hg	25-Aug-99	Sediment Samples	1.76	ppm	000
MR-8	Hg	25-Aug-99	Sediment Samples	1.71	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-8	U	19-Sep-99	Exchangeable Metals	0.1	ppm	<=W
MR-8	U	19-Sep-99	Metals Bound to Carbonates	0.2	ppm	000
MR-8	U	19-Sep-99	Metals Bound to Iron and Manganese	0.2	ppm	<=W
MR-8	U	19-Sep-99	Metals Bound to Organic Matter	0.2	ppm	<=W
MR-8	U	19-Sep-99	Residual Metals	0.8	ppm	000
MR-8	U	25-Aug-99	Sediment Samples	0.53	ppm	000
MR-8	U	25-Aug-99	Sediment Samples	0.6	ppm	000
MR-8	U	25-Aug-99	Sediment Samples	0.94	ppm	000
MR-8	Ag	19-Sep-99	Exchangeable Metals	0.3	ppm	<=W
MR-8	Ag	19-Sep-99	Metals Bound to Carbonates	0.3	ppm	<=W
MR-8	Ag	19-Sep-99	Metals Bound to Iron and Manganese	0.4	ppm	000
MR-8	Ag	19-Sep-99	Metals Bound to Organic Matter	0.8	ppm	000
MR-8	Ag	19-Sep-99	Residual Metals	0.3	ppm	000
MR-8	Ag	25-Aug-99	Sediment Samples	4.5	ppm	000
MR-8	Ag	25-Aug-99	Sediment Samples	4.1	ppm	000
MR-8	Ag	25-Aug-99	Sediment Samples	1	ppm	000
MR-8	Al	19-Sep-99	Exchangeable Metals	3	ppm	<=W
MR-8	Al	19-Sep-99	Metals Bound to Carbonates	45	ppm	000
MR-8	Al	19-Sep-99	Metals Bound to Iron and Manganese	214	ppm	000
MR-8	Al	19-Sep-99	Metals Bound to Organic Matter	820	ppm	000
MR-8	Al	19-Sep-99	Residual Metals	33100	ppm	000
MR-8	Al	25-Aug-99	Sediment Samples	8670	ppm	000
MR-8	Al	25-Aug-99	Sediment Samples	9230	ppm	000
MR-8	Al	25-Aug-99	Sediment Samples	8870	ppm	000
MR-8	Ba	19-Sep-99	Exchangeable Metals	35.7	ppm	000
MR-8	Ba	19-Sep-99	Metals Bound to Carbonates	29.1	ppm	000
MR-8	Ba	19-Sep-99	Metals Bound to Iron and Manganese	9.1	ppm	000
MR-8	Ba	19-Sep-99	Metals Bound to Organic Matter	10.2	ppm	000
MR-8	Ba	19-Sep-99	Residual Metals	557	ppm	000
MR-8	Ba	25-Aug-99	Sediment Samples	142	ppm	000
MR-8	Ba	25-Aug-99	Sediment Samples	143	ppm	000
MR-8	Ba	25-Aug-99	Sediment Samples	141	ppm	000
MR-8	Be	19-Sep-99	Exchangeable Metals	0.04	ppm	<=W
MR-8	Be	19-Sep-99	Metals Bound to Carbonates	0.04	ppm	<=W
MR-8	Be	19-Sep-99	Metals Bound to Iron and Manganese	0.05	ppm	<=W
MR-8	Be	19-Sep-99	Metals Bound to Organic Matter	0.05	ppm	<=W
MR-8	Be	19-Sep-99	Residual Metals	1.25	ppm	000
MR-8	Be	25-Aug-99	Sediment Samples	0.4	ppm	000
MR-8	Be	25-Aug-99	Sediment Samples	0.4	ppm	000
MR-8	Be	25-Aug-99	Sediment Samples	0.4	ppm	000
MR-8	Bi	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-8	Bi	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
MR-8	Bi	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
MR-8	Bi	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
MR-8	Bi	19-Sep-99	Residual Metals	0	ppm	ND
MR-8	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
MR-8	Bi	25-Aug-99	Sediment Samples	0	ppm	ND

Station	Parameter	Date	Description	Result	Units	Remark
MR-8	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
MR-8	Ca	19-Sep-99	Exchangeable Metals	1680	ppm	000
MR-8	Ca	19-Sep-99	Metals Bound to Carbonates	557	ppm	000
MR-8	Ca	19-Sep-99	Metals Bound to Iron and Manganese	307	ppm	000
MR-8	Ca	19-Sep-99	Metals Bound to Organic Matter	284	ppm	000
MR-8	Ca	19-Sep-99	Residual Metals	19600	ppm	000
MR-8	Ca	25-Aug-99	Sediment Samples	5840	ppm	000
MR-8	Ca	25-Aug-99	Sediment Samples	5940	ppm	000
MR-8	Ca	25-Aug-99	Sediment Samples	5470	ppm	000
MR-8	Cd	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-8	Cd	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
MR-8	Cd	19-Sep-99	Metals Bound to Iron and Manganese	0.5	ppm	<=W
MR-8	Cd	19-Sep-99	Metals Bound to Organic Matter	0.5	ppm	<=W
MR-8	Cd	19-Sep-99	Residual Metals	0.1	ppm	<=W
MR-8	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
MR-8	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
MR-8	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
MR-8	Cr	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-8	Cr	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
MR-8	Cr	19-Sep-99	Metals Bound to Iron and Manganese	1.1	ppm	000
MR-8	Cr	19-Sep-99	Metals Bound to Organic Matter	5.1	ppm	000
MR-8	Cr	19-Sep-99	Residual Metals	85	ppm	000
MR-8	Cr	25-Aug-99	Sediment Samples	41	ppm	000
MR-8	Cr	25-Aug-99	Sediment Samples	43	ppm	000
MR-8	Cr	25-Aug-99	Sediment Samples	41	ppm	000
MR-8	Fe	19-Sep-99	Exchangeable Metals	7	ppm	000
MR-8	Fe	19-Sep-99	Metals Bound to Carbonates	417	ppm	000
MR-8	Fe	19-Sep-99	Metals Bound to Iron and Manganese	1770	ppm	000
MR-8	Fe	19-Sep-99	Metals Bound to Organic Matter	613	ppm	000
MR-8	Fe	19-Sep-99	Residual Metals	29600	ppm	000
MR-8	Fe	25-Aug-99	Sediment Samples	23000	ppm	000
MR-8	Fe	25-Aug-99	Sediment Samples	24100	ppm	000
MR-8	Fe	25-Aug-99	Sediment Samples	24400	ppm	000
MR-8	K	19-Sep-99	Exchangeable Metals	107	ppm	000
MR-8	K	19-Sep-99	Metals Bound to Carbonates	80	ppm	<=W
MR-8	K	19-Sep-99	Metals Bound to Iron and Manganese	100	ppm	<=W
MR-8	K	19-Sep-99	Metals Bound to Organic Matter	100	ppm	<=W
MR-8	K	19-Sep-99	Residual Metals	15200	ppm	000
MR-8	K	25-Aug-99	Sediment Samples	763	ppm	000
MR-8	K	25-Aug-99	Sediment Samples	699	ppm	000
MR-8	K	25-Aug-99	Sediment Samples	652	ppm	000
MR-8	Mg	19-Sep-99	Exchangeable Metals	92	ppm	000
MR-8	Mg	19-Sep-99	Metals Bound to Carbonates	28	ppm	000
MR-8	Mg	19-Sep-99	Metals Bound to Iron and Manganese	254	ppm	000
MR-8	Mg	19-Sep-99	Metals Bound to Organic Matter	610	ppm	000
MR-8	Mg	19-Sep-99	Residual Metals	8040	ppm	000
MR-8	Mg	25-Aug-99	Sediment Samples	6760	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-8	Mg	25-Aug-99	Sediment Samples	7110	ppm	000
MR-8	Mg	25-Aug-99	Sediment Samples	6620	ppm	000
MR-8	Mn	19-Sep-99	Exchangeable Metals	114	ppm	000
MR-8	Mn	19-Sep-99	Metals Bound to Carbonates	74.6	ppm	000
MR-8	Mn	19-Sep-99	Metals Bound to Iron and Manganese	38.8	ppm	000
MR-8	Mn	19-Sep-99	Metals Bound to Organic Matter	20	ppm	000
MR-8	Mn	19-Sep-99	Residual Metals	294	ppm	000
MR-8	Mn	25-Aug-99	Sediment Samples	329	ppm	000
MR-8	Mn	25-Aug-99	Sediment Samples	329	ppm	000
MR-8	Mn	25-Aug-99	Sediment Samples	323	ppm	000
MR-8	Mo	19-Sep-99	Exchangeable Metals	2	ppm	<=W
MR-8	Mo	19-Sep-99	Metals Bound to Carbonates	1	ppm	<=W
MR-8	Mo	19-Sep-99	Metals Bound to Iron and Manganese	2	ppm	<=W
MR-8	Mo	19-Sep-99	Metals Bound to Organic Matter	2	ppm	<=W
MR-8	Mo	19-Sep-99	Residual Metals	5	ppm	<=W
MR-8	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
MR-8	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
MR-8	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
MR-8	Na	19-Sep-99	Exchangeable Metals	0	ppm	ND
MR-8	Na	19-Sep-99	Metals Bound to Carbonates	0	ppm	ND
MR-8	Na	19-Sep-99	Metals Bound to Iron and Manganese	0	ppm	ND
MR-8	Na	19-Sep-99	Metals Bound to Organic Matter	0	ppm	ND
MR-8	Na	19-Sep-99	Residual Metals	0	ppm	ND
MR-8	Na	25-Aug-99	Sediment Samples	150	ppm	000
MR-8	Na	25-Aug-99	Sediment Samples	133	ppm	000
MR-8	Na	25-Aug-99	Sediment Samples	133	ppm	000
MR-8	P	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-8	P	19-Sep-99	Metals Bound to Carbonates	22	ppm	000
MR-8	P	19-Sep-99	Metals Bound to Iron and Manganese	14	ppm	000
MR-8	P	19-Sep-99	Metals Bound to Organic Matter	40	ppm	000
MR-8	P	19-Sep-99	Residual Metals	1180	ppm	000
MR-8	P	25-Aug-99	Sediment Samples	1070	ppm	000
MR-8	P	25-Aug-99	Sediment Samples	1150	ppm	000
MR-8	P	25-Aug-99	Sediment Samples	1110	ppm	000
MR-8	S	19-Sep-99	Exchangeable Metals	121	ppm	000
MR-8	S	19-Sep-99	Metals Bound to Carbonates	32	ppm	000
MR-8	S	19-Sep-99	Metals Bound to Iron and Manganese	50	ppm	000
MR-8	S	19-Sep-99	Metals Bound to Organic Matter	907	ppm	000
MR-8	S	19-Sep-99	Residual Metals	0	ppm	ND
MR-8	S	25-Aug-99	Sediment Samples	0	ppm	ND
MR-8	S	25-Aug-99	Sediment Samples	0	ppm	ND
MR-8	S	25-Aug-99	Sediment Samples	0	ppm	ND
MR-8	Sb	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-8	Sb	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
MR-8	Sb	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
MR-8	Sb	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
MR-8	Sb	19-Sep-99	Residual Metals	0	ppm	ND

Station	Parameter	Date	Description	Result	Units	Remark
MR-8	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
MR-8	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
MR-8	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
MR-8	Se	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-8	Se	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
MR-8	Se	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
MR-8	Se	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
MR-8	Se	19-Sep-99	Residual Metals	0	ppm	ND
MR-8	Se	25-Aug-99	Sediment Samples	0	ppm	ND
MR-8	Se	25-Aug-99	Sediment Samples	0	ppm	ND
MR-8	Se	25-Aug-99	Sediment Samples	0	ppm	ND
MR-8	Sr	19-Sep-99	Exchangeable Metals	7.7	ppm	000
MR-8	Sr	19-Sep-99	Metals Bound to Carbonates	2.8	ppm	000
MR-8	Sr	19-Sep-99	Metals Bound to Iron and Manganese	0.8	ppm	000
MR-8	Sr	19-Sep-99	Metals Bound to Organic Matter	1.1	ppm	000
MR-8	Sr	19-Sep-99	Residual Metals	232	ppm	000
MR-8	Sr	25-Aug-99	Sediment Samples	24.1	ppm	000
MR-8	Sr	25-Aug-99	Sediment Samples	24	ppm	000
MR-8	Sr	25-Aug-99	Sediment Samples	22.4	ppm	000
MR-8	Ti	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-8	Ti	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
MR-8	Ti	19-Sep-99	Metals Bound to Iron and Manganese	0.5	ppm	<=W
MR-8	Ti	19-Sep-99	Metals Bound to Organic Matter	1.3	ppm	000
MR-8	Ti	19-Sep-99	Residual Metals	3960	ppm	000
MR-8	Ti	25-Aug-99	Sediment Samples	220	ppm	000
MR-8	Ti	25-Aug-99	Sediment Samples	225	ppm	000
MR-8	Ti	25-Aug-99	Sediment Samples	275	ppm	000
MR-8	V	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-8	V	19-Sep-99	Metals Bound to Carbonates	1.2	ppm	000
MR-8	V	19-Sep-99	Metals Bound to Iron and Manganese	1.4	ppm	000
MR-8	V	19-Sep-99	Metals Bound to Organic Matter	1.7	ppm	000
MR-8	V	19-Sep-99	Residual Metals	72	ppm	000
MR-8	V	25-Aug-99	Sediment Samples	28	ppm	000
MR-8	V	25-Aug-99	Sediment Samples	30	ppm	000
MR-8	V	25-Aug-99	Sediment Samples	28	ppm	000
MR-8	Zn	19-Sep-99	Exchangeable Metals	0.7	ppm	000
MR-8	Zn	19-Sep-99	Metals Bound to Carbonates	6	ppm	000
MR-8	Zn	19-Sep-99	Metals Bound to Iron and Manganese	14	ppm	000
MR-8	Zn	19-Sep-99	Metals Bound to Organic Matter	11.3	ppm	000
MR-8	Zn	19-Sep-99	Residual Metals	63	ppm	000
MR-8	Zn	25-Aug-99	Sediment Samples	96	ppm	000
MR-8	Zn	25-Aug-99	Sediment Samples	106	ppm	000
MR-8	Zn	25-Aug-99	Sediment Samples	103	ppm	000
MR-11	As	19-Sep-99	Exchangeable Metals	4.4	ppm	000
MR-11	As	19-Sep-99	Metals Bound to Carbonates	47.8	ppm	000
MR-11	As	19-Sep-99	Metals Bound to Iron and Manganese	181	ppm	000
MR-11	As	19-Sep-99	Metals Bound to Organic Matter	12.5	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-11	As	19-Sep-99	Residual Metals	151	ppm	000
MR-11	As	25-Aug-99	Sediment Samples	656	ppm	000
MR-11	As	25-Aug-99	Sediment Samples	1310	ppm	000
MR-11	As	25-Aug-99	Sediment Samples	838	ppm	000
MR-11	Co	19-Sep-99	Exchangeable Metals	17.6	ppm	000
MR-11	Co	19-Sep-99	Metals Bound to Carbonates	98.5	ppm	000
MR-11	Co	19-Sep-99	Metals Bound to Iron and Manganese	425	ppm	000
MR-11	Co	19-Sep-99	Metals Bound to Organic Matter	365	ppm	000
MR-11	Co	19-Sep-99	Residual Metals	53	ppm	000
MR-11	Co	25-Aug-99	Sediment Samples	1030	ppm	000
MR-11	Co	25-Aug-99	Sediment Samples	1600	ppm	000
MR-11	Co	25-Aug-99	Sediment Samples	934	ppm	000
MR-11	Cu	19-Sep-99	Exchangeable Metals	0.8	ppm	000
MR-11	Cu	19-Sep-99	Metals Bound to Carbonates	1.8	ppm	000
MR-11	Cu	19-Sep-99	Metals Bound to Iron and Manganese	0.4	ppm	000
MR-11	Cu	19-Sep-99	Metals Bound to Organic Matter	136	ppm	000
MR-11	Cu	19-Sep-99	Residual Metals	28.3	ppm	000
MR-11	Cu	25-Aug-99	Sediment Samples	188	ppm	000
MR-11	Cu	25-Aug-99	Sediment Samples	311	ppm	000
MR-11	Cu	25-Aug-99	Sediment Samples	232	ppm	000
MR-11	Ni	19-Sep-99	Exchangeable Metals	7	ppm	000
MR-11	Ni	19-Sep-99	Metals Bound to Carbonates	39	ppm	000
MR-11	Ni	19-Sep-99	Metals Bound to Iron and Manganese	242	ppm	000
MR-11	Ni	19-Sep-99	Metals Bound to Organic Matter	283	ppm	000
MR-11	Ni	19-Sep-99	Residual Metals	92	ppm	000
MR-11	Ni	25-Aug-99	Sediment Samples	736	ppm	000
MR-11	Ni	25-Aug-99	Sediment Samples	2180	ppm	000
MR-11	Ni	25-Aug-99	Sediment Samples	2170	ppm	000
MR-11	Pb	19-Sep-99	Exchangeable Metals	4	ppm	<=W
MR-11	Pb	19-Sep-99	Metals Bound to Carbonates	6	ppm	000
MR-11	Pb	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	000
MR-11	Pb	19-Sep-99	Metals Bound to Organic Matter	6	ppm	000
MR-11	Pb	19-Sep-99	Residual Metals	36	ppm	000
MR-11	Pb	25-Aug-99	Sediment Samples	65	ppm	000
MR-11	Pb	25-Aug-99	Sediment Samples	84	ppm	000
MR-11	Pb	25-Aug-99	Sediment Samples	48	ppm	000
MR-11	Hg	19-Sep-99	Exchangeable Metals	0.01	ppm	<=W
MR-11	Hg	19-Sep-99	Metals Bound to Carbonates	0.01	ppm	<=W
MR-11	Hg	19-Sep-99	Metals Bound to Iron and Manganese	0.02	ppm	<=W
MR-11	Hg	19-Sep-99	Metals Bound to Organic Matter	0.02	ppm	<=W
MR-11	Hg	19-Sep-99	Residual Metals	2.38	ppm	000
MR-11	Hg	25-Aug-99	Sediment Samples	2.6	ppm	000
MR-11	Hg	25-Aug-99	Sediment Samples	2.42	ppm	000
MR-11	Hg	25-Aug-99	Sediment Samples	3.52	ppm	000
MR-11	U	19-Sep-99	Exchangeable Metals	0.1	ppm	<=W
MR-11	U	19-Sep-99	Metals Bound to Carbonates	0.2	ppm	000
MR-11	U	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-11	U	19-Sep-99	Metals Bound to Organic Matter	0.2	ppm	<=W
MR-11	U	19-Sep-99	Residual Metals	0.6	ppm	000
MR-11	U	25-Aug-99	Sediment Samples	1.13	ppm	000
MR-11	U	25-Aug-99	Sediment Samples	1.22	ppm	000
MR-11	U	25-Aug-99	Sediment Samples	1.26	ppm	000
MR-11	Ag	19-Sep-99	Exchangeable Metals	0.3	ppm	<=W
MR-11	Ag	19-Sep-99	Metals Bound to Carbonates	0.3	ppm	<=W
MR-11	Ag	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
MR-11	Ag	19-Sep-99	Metals Bound to Organic Matter	0.3	ppm	<=W
MR-11	Ag	19-Sep-99	Residual Metals	14.6	ppm	000
MR-11	Ag	25-Aug-99	Sediment Samples	8.2	ppm	000
MR-11	Ag	25-Aug-99	Sediment Samples	2.4	ppm	000
MR-11	Ag	25-Aug-99	Sediment Samples	12.3	ppm	000
MR-11	Al	19-Sep-99	Exchangeable Metals	3	ppm	<=W
MR-11	Al	19-Sep-99	Metals Bound to Carbonates	58	ppm	000
MR-11	Al	19-Sep-99	Metals Bound to Iron and Manganese	931	ppm	000
MR-11	Al	19-Sep-99	Metals Bound to Organic Matter	3630	ppm	000
MR-11	Al	19-Sep-99	Residual Metals	35500	ppm	000
MR-11	Al	25-Aug-99	Sediment Samples	13600	ppm	000
MR-11	Al	25-Aug-99	Sediment Samples	14400	ppm	000
MR-11	Al	25-Aug-99	Sediment Samples	15400	ppm	000
MR-11	Ba	19-Sep-99	Exchangeable Metals	59.6	ppm	000
MR-11	Ba	19-Sep-99	Metals Bound to Carbonates	65.8	ppm	000
MR-11	Ba	19-Sep-99	Metals Bound to Iron and Manganese	94.5	ppm	000
MR-11	Ba	19-Sep-99	Metals Bound to Organic Matter	10.2	ppm	000
MR-11	Ba	19-Sep-99	Residual Metals	427	ppm	000
MR-11	Ba	25-Aug-99	Sediment Samples	46	ppm	000
MR-11	Ba	25-Aug-99	Sediment Samples	37	ppm	000
MR-11	Ba	25-Aug-99	Sediment Samples	44	ppm	000
MR-11	Be	19-Sep-99	Exchangeable Metals	0.04	ppm	<=W
MR-11	Be	19-Sep-99	Metals Bound to Carbonates	0.05	ppm	000
MR-11	Be	19-Sep-99	Metals Bound to Iron and Manganese	0.31	ppm	000
MR-11	Be	19-Sep-99	Metals Bound to Organic Matter	0.07	ppm	000
MR-11	Be	19-Sep-99	Residual Metals	0.77	ppm	000
MR-11	Be	25-Aug-99	Sediment Samples	0.7	ppm	000
MR-11	Be	25-Aug-99	Sediment Samples	0.8	ppm	000
MR-11	Be	25-Aug-99	Sediment Samples	0.8	ppm	000
MR-11	Bi	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-11	Bi	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
MR-11	Bi	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
MR-11	Bi	19-Sep-99	Metals Bound to Organic Matter	16	ppm	000
MR-11	Bi	19-Sep-99	Residual Metals	0	ppm	ND
MR-11	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
MR-11	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
MR-11	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
MR-11	Ca	19-Sep-99	Exchangeable Metals	6170	ppm	000
MR-11	Ca	19-Sep-99	Metals Bound to Carbonates	3520	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-11	Ca	19-Sep-99	Metals Bound to Iron and Manganese	3320	ppm	000
MR-11	Ca	19-Sep-99	Metals Bound to Organic Matter	700	ppm	000
MR-11	Ca	19-Sep-99	Residual Metals	6930	ppm	000
MR-11	Ca	25-Aug-99	Sediment Samples	16000	ppm	000
MR-11	Ca	25-Aug-99	Sediment Samples	17400	ppm	000
MR-11	Ca	25-Aug-99	Sediment Samples	18100	ppm	000
MR-11	Cd	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-11	Cd	19-Sep-99	Metals Bound to Carbonates	0.6	ppm	000
MR-11	Cd	19-Sep-99	Metals Bound to Iron and Manganese	1	ppm	000
MR-11	Cd	19-Sep-99	Metals Bound to Organic Matter	0.5	ppm	<=W
MR-11	Cd	19-Sep-99	Residual Metals	0.1	ppm	<=W
MR-11	Cd	25-Aug-99	Sediment Samples	0.8	ppm	000
MR-11	Cd	25-Aug-99	Sediment Samples	1.1	ppm	000
MR-11	Cd	25-Aug-99	Sediment Samples	0.8	ppm	000
MR-11	Cr	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-11	Cr	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
MR-11	Cr	19-Sep-99	Metals Bound to Iron and Manganese	4.9	ppm	000
MR-11	Cr	19-Sep-99	Metals Bound to Organic Matter	14.5	ppm	000
MR-11	Cr	19-Sep-99	Residual Metals	42	ppm	000
MR-11	Cr	25-Aug-99	Sediment Samples	42	ppm	000
MR-11	Cr	25-Aug-99	Sediment Samples	45	ppm	000
MR-11	Cr	25-Aug-99	Sediment Samples	35	ppm	000
MR-11	Fe	19-Sep-99	Exchangeable Metals	5	ppm	000
MR-11	Fe	19-Sep-99	Metals Bound to Carbonates	784	ppm	000
MR-11	Fe	19-Sep-99	Metals Bound to Iron and Manganese	10100	ppm	000
MR-11	Fe	19-Sep-99	Metals Bound to Organic Matter	7120	ppm	000
MR-11	Fe	19-Sep-99	Residual Metals	22000	ppm	000
MR-11	Fe	25-Aug-99	Sediment Samples	30200	ppm	000
MR-11	Fe	25-Aug-99	Sediment Samples	32200	ppm	000
MR-11	Fe	25-Aug-99	Sediment Samples	29800	ppm	000
MR-11	K	19-Sep-99	Exchangeable Metals	142	ppm	000
MR-11	K	19-Sep-99	Metals Bound to Carbonates	80	ppm	<=W
MR-11	K	19-Sep-99	Metals Bound to Iron and Manganese	100	ppm	<=W
MR-11	K	19-Sep-99	Metals Bound to Organic Matter	100	ppm	<=W
MR-11	K	19-Sep-99	Residual Metals	10300	ppm	000
MR-11	K	25-Aug-99	Sediment Samples	1300	ppm	000
MR-11	K	25-Aug-99	Sediment Samples	1300	ppm	000
MR-11	K	25-Aug-99	Sediment Samples	1430	ppm	000
MR-11	Mg	19-Sep-99	Exchangeable Metals	285	ppm	000
MR-11	Mg	19-Sep-99	Metals Bound to Carbonates	100	ppm	000
MR-11	Mg	19-Sep-99	Metals Bound to Iron and Manganese	716	ppm	000
MR-11	Mg	19-Sep-99	Metals Bound to Organic Matter	1410	ppm	000
MR-11	Mg	19-Sep-99	Residual Metals	8350	ppm	000
MR-11	Mg	25-Aug-99	Sediment Samples	7090	ppm	000
MR-11	Mg	25-Aug-99	Sediment Samples	7580	ppm	000
MR-11	Mg	25-Aug-99	Sediment Samples	7810	ppm	000
MR-11	Mn	19-Sep-99	Exchangeable Metals	434	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-11	Mn	19-Sep-99	Metals Bound to Carbonates	446	ppm	000
MR-11	Mn	19-Sep-99	Metals Bound to Iron and Manganese	381	ppm	000
MR-11	Mn	19-Sep-99	Metals Bound to Organic Matter	72.1	ppm	000
MR-11	Mn	19-Sep-99	Residual Metals	179	ppm	000
MR-11	Mn	25-Aug-99	Sediment Samples	850	ppm	000
MR-11	Mn	25-Aug-99	Sediment Samples	674	ppm	000
MR-11	Mn	25-Aug-99	Sediment Samples	598	ppm	000
MR-11	Mo	19-Sep-99	Exchangeable Metals	2	ppm	<=W
MR-11	Mo	19-Sep-99	Metals Bound to Carbonates	1	ppm	<=W
MR-11	Mo	19-Sep-99	Metals Bound to Iron and Manganese	2	ppm	<=W
MR-11	Mo	19-Sep-99	Metals Bound to Organic Matter	2	ppm	<=W
MR-11	Mo	19-Sep-99	Residual Metals	5	ppm	<=W
MR-11	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
MR-11	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
MR-11	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
MR-11	Na	19-Sep-99	Exchangeable Metals	0	ppm	ND
MR-11	Na	19-Sep-99	Metals Bound to Carbonates	0	ppm	ND
MR-11	Na	19-Sep-99	Metals Bound to Iron and Manganese	0	ppm	ND
MR-11	Na	19-Sep-99	Metals Bound to Organic Matter	0	ppm	ND
MR-11	Na	19-Sep-99	Residual Metals	0	ppm	ND
MR-11	Na	25-Aug-99	Sediment Samples	205	ppm	000
MR-11	Na	25-Aug-99	Sediment Samples	202	ppm	000
MR-11	Na	25-Aug-99	Sediment Samples	222	ppm	000
MR-11	P	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-11	P	19-Sep-99	Metals Bound to Carbonates	24	ppm	000
MR-11	P	19-Sep-99	Metals Bound to Iron and Manganese	122	ppm	000
MR-11	P	19-Sep-99	Metals Bound to Organic Matter	99	ppm	000
MR-11	P	19-Sep-99	Residual Metals	1220	ppm	000
MR-11	P	25-Aug-99	Sediment Samples	1040	ppm	000
MR-11	P	25-Aug-99	Sediment Samples	1080	ppm	000
MR-11	P	25-Aug-99	Sediment Samples	1060	ppm	000
MR-11	S	19-Sep-99	Exchangeable Metals	303	ppm	000
MR-11	S	19-Sep-99	Metals Bound to Carbonates	97	ppm	000
MR-11	S	19-Sep-99	Metals Bound to Iron and Manganese	787	ppm	000
MR-11	S	19-Sep-99	Metals Bound to Organic Matter	6510	ppm	000
MR-11	S	19-Sep-99	Residual Metals	0	ppm	ND
MR-11	S	25-Aug-99	Sediment Samples	0	ppm	ND
MR-11	S	25-Aug-99	Sediment Samples	0	ppm	ND
MR-11	S	25-Aug-99	Sediment Samples	0	ppm	ND
MR-11	Sb	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-11	Sb	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
MR-11	Sb	19-Sep-99	Metals Bound to Iron and Manganese	66	ppm	000
MR-11	Sb	19-Sep-99	Metals Bound to Organic Matter	48	ppm	000
MR-11	Sb	19-Sep-99	Residual Metals	0	ppm	ND
MR-11	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
MR-11	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
MR-11	Sb	25-Aug-99	Sediment Samples	0	ppm	ND

Station	Parameter	Date	Description	Result	Units	Remark
MR-11	Se	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-11	Se	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
MR-11	Se	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
MR-11	Se	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
MR-11	Se	19-Sep-99	Residual Metals	0	ppm	ND
MR-11	Se	25-Aug-99	Sediment Samples	0	ppm	ND
MR-11	Se	25-Aug-99	Sediment Samples	0	ppm	ND
MR-11	Se	25-Aug-99	Sediment Samples	0	ppm	ND
MR-11	Sr	19-Sep-99	Exchangeable Metals	41.1	ppm	000
MR-11	Sr	19-Sep-99	Metals Bound to Carbonates	22.9	ppm	000
MR-11	Sr	19-Sep-99	Metals Bound to Iron and Manganese	20.8	ppm	000
MR-11	Sr	19-Sep-99	Metals Bound to Organic Matter	4.7	ppm	000
MR-11	Sr	19-Sep-99	Residual Metals	111	ppm	000
MR-11	Sr	25-Aug-99	Sediment Samples	86.6	ppm	000
MR-11	Sr	25-Aug-99	Sediment Samples	95.5	ppm	000
MR-11	Sr	25-Aug-99	Sediment Samples	102	ppm	000
MR-11	Ti	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-11	Ti	19-Sep-99	Metals Bound to Carbonates	0.9	ppm	000
MR-11	Ti	19-Sep-99	Metals Bound to Iron and Manganese	0.9	ppm	000
MR-11	Ti	19-Sep-99	Metals Bound to Organic Matter	5.5	ppm	000
MR-11	Ti	19-Sep-99	Residual Metals	2530	ppm	000
MR-11	Ti	25-Aug-99	Sediment Samples	392	ppm	000
MR-11	Ti	25-Aug-99	Sediment Samples	401	ppm	000
MR-11	Ti	25-Aug-99	Sediment Samples	454	ppm	000
MR-11	V	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-11	V	19-Sep-99	Metals Bound to Carbonates	1.3	ppm	000
MR-11	V	19-Sep-99	Metals Bound to Iron and Manganese	6.7	ppm	000
MR-11	V	19-Sep-99	Metals Bound to Organic Matter	8.6	ppm	000
MR-11	V	19-Sep-99	Residual Metals	51	ppm	000
MR-11	V	25-Aug-99	Sediment Samples	37	ppm	000
MR-11	V	25-Aug-99	Sediment Samples	34	ppm	000
MR-11	V	25-Aug-99	Sediment Samples	40	ppm	000
MR-11	Zn	19-Sep-99	Exchangeable Metals	2.1	ppm	000
MR-11	Zn	19-Sep-99	Metals Bound to Carbonates	29.1	ppm	000
MR-11	Zn	19-Sep-99	Metals Bound to Iron and Manganese	105	ppm	000
MR-11	Zn	19-Sep-99	Metals Bound to Organic Matter	58.4	ppm	000
MR-11	Zn	19-Sep-99	Residual Metals	68	ppm	000
MR-11	Zn	25-Aug-99	Sediment Samples	247	ppm	000
MR-11	Zn	25-Aug-99	Sediment Samples	305	ppm	000
MR-11	Zn	25-Aug-99	Sediment Samples	236	ppm	000
MR-13	As	19-Sep-99	Exchangeable Metals	0.8	ppm	000
MR-13	As	19-Sep-99	Metals Bound to Carbonates	4.5	ppm	000
MR-13	As	19-Sep-99	Metals Bound to Iron and Manganese	13	ppm	000
MR-13	As	19-Sep-99	Metals Bound to Organic Matter	0.6	ppm	000
MR-13	As	19-Sep-99	Residual Metals	15.6	ppm	000
MR-13	As	25-Aug-99	Sediment Samples	19	ppm	000
MR-13	As	25-Aug-99	Sediment Samples	14	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-13	As	25-Aug-99	Sediment Samples	10	ppm	000
MR-13	Co	19-Sep-99	Exchangeable Metals	0.9	ppm	000
MR-13	Co	19-Sep-99	Metals Bound to Carbonates	9	ppm	000
MR-13	Co	19-Sep-99	Metals Bound to Iron and Manganese	39.9	ppm	000
MR-13	Co	19-Sep-99	Metals Bound to Organic Matter	16.3	ppm	000
MR-13	Co	19-Sep-99	Residual Metals	16	ppm	000
MR-13	Co	25-Aug-99	Sediment Samples	54	ppm	000
MR-13	Co	25-Aug-99	Sediment Samples	51	ppm	000
MR-13	Co	25-Aug-99	Sediment Samples	27	ppm	000
MR-13	Cu	19-Sep-99	Exchangeable Metals	0.5	ppm	000
MR-13	Cu	19-Sep-99	Metals Bound to Carbonates	0.3	ppm	000
MR-13	Cu	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
MR-13	Cu	19-Sep-99	Metals Bound to Organic Matter	9.1	ppm	000
MR-13	Cu	19-Sep-99	Residual Metals	9.3	ppm	000
MR-13	Cu	25-Aug-99	Sediment Samples	15	ppm	000
MR-13	Cu	25-Aug-99	Sediment Samples	12	ppm	000
MR-13	Cu	25-Aug-99	Sediment Samples	10	ppm	000
MR-13	Ni	19-Sep-99	Exchangeable Metals	2	ppm	<=W
MR-13	Ni	19-Sep-99	Metals Bound to Carbonates	2	ppm	<=W
MR-13	Ni	19-Sep-99	Metals Bound to Iron and Manganese	18	ppm	000
MR-13	Ni	19-Sep-99	Metals Bound to Organic Matter	13	ppm	000
MR-13	Ni	19-Sep-99	Residual Metals	19	ppm	000
MR-13	Ni	25-Aug-99	Sediment Samples	34	ppm	000
MR-13	Ni	25-Aug-99	Sediment Samples	33	ppm	000
MR-13	Ni	25-Aug-99	Sediment Samples	26	ppm	000
MR-13	Pb	19-Sep-99	Exchangeable Metals	4	ppm	<=W
MR-13	Pb	19-Sep-99	Metals Bound to Carbonates	5	ppm	000
MR-13	Pb	19-Sep-99	Metals Bound to Iron and Manganese	5	ppm	<=W
MR-13	Pb	19-Sep-99	Metals Bound to Organic Matter	5	ppm	<=W
MR-13	Pb	19-Sep-99	Residual Metals	21	ppm	000
MR-13	Pb	25-Aug-99	Sediment Samples	15	ppm	000
MR-13	Pb	25-Aug-99	Sediment Samples	15	ppm	000
MR-13	Pb	25-Aug-99	Sediment Samples	6	ppm	000
MR-13	Hg	19-Sep-99	Exchangeable Metals	0.01	ppm	<=W
MR-13	Hg	19-Sep-99	Metals Bound to Carbonates	0.01	ppm	<=W
MR-13	Hg	19-Sep-99	Metals Bound to Iron and Manganese	0.02	ppm	<=W
MR-13	Hg	19-Sep-99	Metals Bound to Organic Matter	0.02	ppm	<=W
MR-13	Hg	19-Sep-99	Residual Metals	0.14	ppm	000
MR-13	Hg	25-Aug-99	Sediment Samples	0.03	ppm	000
MR-13	Hg	25-Aug-99	Sediment Samples	0.03	ppm	000
MR-13	Hg	25-Aug-99	Sediment Samples	0.03	ppm	000
MR-13	U	19-Sep-99	Exchangeable Metals	0.1	ppm	<=W
MR-13	U	19-Sep-99	Metals Bound to Carbonates	0.6	ppm	000
MR-13	U	19-Sep-99	Metals Bound to Iron and Manganese	0.4	ppm	000
MR-13	U	19-Sep-99	Metals Bound to Organic Matter	0.2	ppm	000
MR-13	U	19-Sep-99	Residual Metals	1.1	ppm	000
MR-13	U	25-Aug-99	Sediment Samples	1.03	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-13	U	25-Aug-99	Sediment Samples	0.83	ppm	000
MR-13	U	25-Aug-99	Sediment Samples	0.81	ppm	000
MR-13	Ag	19-Sep-99	Exchangeable Metals	0.3	ppm	<=W
MR-13	Ag	19-Sep-99	Metals Bound to Carbonates	0.3	ppm	<=W
MR-13	Ag	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
MR-13	Ag	19-Sep-99	Metals Bound to Organic Matter	0.3	ppm	<=W
MR-13	Ag	19-Sep-99	Residual Metals	0.1	ppm	<=W
MR-13	Ag	25-Aug-99	Sediment Samples	0.8	ppm	<=W
MR-13	Ag	25-Aug-99	Sediment Samples	0.8	ppm	<=W
MR-13	Ag	25-Aug-99	Sediment Samples	0.8	ppm	<=W
MR-13	Al	19-Sep-99	Exchangeable Metals	3	ppm	<=W
MR-13	Al	19-Sep-99	Metals Bound to Carbonates	49	ppm	000
MR-13	Al	19-Sep-99	Metals Bound to Iron and Manganese	1130	ppm	000
MR-13	Al	19-Sep-99	Metals Bound to Organic Matter	1980	ppm	000
MR-13	Al	19-Sep-99	Residual Metals	45600	ppm	000
MR-13	Al	25-Aug-99	Sediment Samples	10100	ppm	000
MR-13	Al	25-Aug-99	Sediment Samples	8700	ppm	000
MR-13	Al	25-Aug-99	Sediment Samples	14000	ppm	000
MR-13	Ba	19-Sep-99	Exchangeable Metals	48	ppm	000
MR-13	Ba	19-Sep-99	Metals Bound to Carbonates	55.4	ppm	000
MR-13	Ba	19-Sep-99	Metals Bound to Iron and Manganese	54.3	ppm	000
MR-13	Ba	19-Sep-99	Metals Bound to Organic Matter	16.7	ppm	000
MR-13	Ba	19-Sep-99	Residual Metals	430	ppm	000
MR-13	Ba	25-Aug-99	Sediment Samples	174	ppm	000
MR-13	Ba	25-Aug-99	Sediment Samples	144	ppm	000
MR-13	Ba	25-Aug-99	Sediment Samples	172	ppm	000
MR-13	Be	19-Sep-99	Exchangeable Metals	0.04	ppm	<=W
MR-13	Be	19-Sep-99	Metals Bound to Carbonates	0.04	ppm	<=W
MR-13	Be	19-Sep-99	Metals Bound to Iron and Manganese	0.23	ppm	000
MR-13	Be	19-Sep-99	Metals Bound to Organic Matter	0.05	ppm	<=W
MR-13	Be	19-Sep-99	Residual Metals	1.07	ppm	000
MR-13	Be	25-Aug-99	Sediment Samples	0.5	ppm	000
MR-13	Be	25-Aug-99	Sediment Samples	0.5	ppm	000
MR-13	Be	25-Aug-99	Sediment Samples	0.7	ppm	000
MR-13	Bi	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-13	Bi	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
MR-13	Bi	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
MR-13	Bi	19-Sep-99	Metals Bound to Organic Matter	10	ppm	000
MR-13	Bi	19-Sep-99	Residual Metals	0	ppm	ND
MR-13	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
MR-13	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
MR-13	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
MR-13	Ca	19-Sep-99	Exchangeable Metals	4170	ppm	000
MR-13	Ca	19-Sep-99	Metals Bound to Carbonates	6840	ppm	000
MR-13	Ca	19-Sep-99	Metals Bound to Iron and Manganese	2830	ppm	000
MR-13	Ca	19-Sep-99	Metals Bound to Organic Matter	409	ppm	000
MR-13	Ca	19-Sep-99	Residual Metals	12800	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-13	Ca	25-Aug-99	Sediment Samples	8760	ppm	000
MR-13	Ca	25-Aug-99	Sediment Samples	7300	ppm	000
MR-13	Ca	25-Aug-99	Sediment Samples	5200	ppm	000
MR-13	Cd	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-13	Cd	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
MR-13	Cd	19-Sep-99	Metals Bound to Iron and Manganese	0.5	ppm	000
MR-13	Cd	19-Sep-99	Metals Bound to Organic Matter	0.5	ppm	<=W
MR-13	Cd	19-Sep-99	Residual Metals	0.1	ppm	<=W
MR-13	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
MR-13	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
MR-13	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
MR-13	Cr	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-13	Cr	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
MR-13	Cr	19-Sep-99	Metals Bound to Iron and Manganese	1.2	ppm	000
MR-13	Cr	19-Sep-99	Metals Bound to Organic Matter	6.3	ppm	000
MR-13	Cr	19-Sep-99	Residual Metals	33	ppm	000
MR-13	Cr	25-Aug-99	Sediment Samples	21	ppm	000
MR-13	Cr	25-Aug-99	Sediment Samples	18	ppm	000
MR-13	Cr	25-Aug-99	Sediment Samples	26	ppm	000
MR-13	Fe	19-Sep-99	Exchangeable Metals	4	ppm	000
MR-13	Fe	19-Sep-99	Metals Bound to Carbonates	208	ppm	000
MR-13	Fe	19-Sep-99	Metals Bound to Iron and Manganese	5110	ppm	000
MR-13	Fe	19-Sep-99	Metals Bound to Organic Matter	1520	ppm	000
MR-13	Fe	19-Sep-99	Residual Metals	22000	ppm	000
MR-13	Fe	25-Aug-99	Sediment Samples	18500	ppm	000
MR-13	Fe	25-Aug-99	Sediment Samples	16700	ppm	000
MR-13	Fe	25-Aug-99	Sediment Samples	25100	ppm	000
MR-13	K	19-Sep-99	Exchangeable Metals	385	ppm	000
MR-13	K	19-Sep-99	Metals Bound to Carbonates	82	ppm	000
MR-13	K	19-Sep-99	Metals Bound to Iron and Manganese	100	ppm	<=W
MR-13	K	19-Sep-99	Metals Bound to Organic Matter	100	ppm	<=W
MR-13	K	19-Sep-99	Residual Metals	10000	ppm	000
MR-13	K	25-Aug-99	Sediment Samples	1110	ppm	000
MR-13	K	25-Aug-99	Sediment Samples	853	ppm	000
MR-13	K	25-Aug-99	Sediment Samples	1470	ppm	000
MR-13	Mg	19-Sep-99	Exchangeable Metals	215	ppm	000
MR-13	Mg	19-Sep-99	Metals Bound to Carbonates	138	ppm	000
MR-13	Mg	19-Sep-99	Metals Bound to Iron and Manganese	668	ppm	000
MR-13	Mg	19-Sep-99	Metals Bound to Organic Matter	666	ppm	000
MR-13	Mg	19-Sep-99	Residual Metals	6930	ppm	000
MR-13	Mg	25-Aug-99	Sediment Samples	3800	ppm	000
MR-13	Mg	25-Aug-99	Sediment Samples	3190	ppm	000
MR-13	Mg	25-Aug-99	Sediment Samples	4710	ppm	000
MR-13	Mn	19-Sep-99	Exchangeable Metals	136	ppm	000
MR-13	Mn	19-Sep-99	Metals Bound to Carbonates	196	ppm	000
MR-13	Mn	19-Sep-99	Metals Bound to Iron and Manganese	178	ppm	000
MR-13	Mn	19-Sep-99	Metals Bound to Organic Matter	25.7	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
MR-13	Mn	19-Sep-99	Residual Metals	272	ppm	000
MR-13	Mn	25-Aug-99	Sediment Samples	510	ppm	000
MR-13	Mn	25-Aug-99	Sediment Samples	384	ppm	000
MR-13	Mn	25-Aug-99	Sediment Samples	377	ppm	000
MR-13	Mo	19-Sep-99	Exchangeable Metals	2	ppm	<=W
MR-13	Mo	19-Sep-99	Metals Bound to Carbonates	1	ppm	<=W
MR-13	Mo	19-Sep-99	Metals Bound to Iron and Manganese	2	ppm	<=W
MR-13	Mo	19-Sep-99	Metals Bound to Organic Matter	2	ppm	<=W
MR-13	Mo	19-Sep-99	Residual Metals	5	ppm	<=W
MR-13	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
MR-13	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
MR-13	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
MR-13	Na	19-Sep-99	Exchangeable Metals	0	ppm	ND
MR-13	Na	19-Sep-99	Metals Bound to Carbonates	0	ppm	ND
MR-13	Na	19-Sep-99	Metals Bound to Iron and Manganese	0	ppm	ND
MR-13	Na	19-Sep-99	Metals Bound to Organic Matter	0	ppm	ND
MR-13	Na	19-Sep-99	Residual Metals	0	ppm	ND
MR-13	Na	25-Aug-99	Sediment Samples	131	ppm	000
MR-13	Na	25-Aug-99	Sediment Samples	85	ppm	000
MR-13	Na	25-Aug-99	Sediment Samples	129	ppm	000
MR-13	P	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-13	P	19-Sep-99	Metals Bound to Carbonates	27	ppm	000
MR-13	P	19-Sep-99	Metals Bound to Iron and Manganese	91	ppm	000
MR-13	P	19-Sep-99	Metals Bound to Organic Matter	71	ppm	000
MR-13	P	19-Sep-99	Residual Metals	930	ppm	000
MR-13	P	25-Aug-99	Sediment Samples	866	ppm	000
MR-13	P	25-Aug-99	Sediment Samples	826	ppm	000
MR-13	P	25-Aug-99	Sediment Samples	839	ppm	000
MR-13	S	19-Sep-99	Exchangeable Metals	125	ppm	000
MR-13	S	19-Sep-99	Metals Bound to Carbonates	41	ppm	000
MR-13	S	19-Sep-99	Metals Bound to Iron and Manganese	416	ppm	000
MR-13	S	19-Sep-99	Metals Bound to Organic Matter	1810	ppm	000
MR-13	S	19-Sep-99	Residual Metals	0	ppm	ND
MR-13	S	25-Aug-99	Sediment Samples	0	ppm	ND
MR-13	S	25-Aug-99	Sediment Samples	0	ppm	ND
MR-13	S	25-Aug-99	Sediment Samples	0	ppm	ND
MR-13	Sb	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-13	Sb	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
MR-13	Sb	19-Sep-99	Metals Bound to Iron and Manganese	28	ppm	000
MR-13	Sb	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
MR-13	Sb	19-Sep-99	Residual Metals	0	ppm	ND
MR-13	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
MR-13	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
MR-13	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
MR-13	Se	19-Sep-99	Exchangeable Metals	8	ppm	<=W
MR-13	Se	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
MR-13	Se	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W

Station	Parameter	Date	Description	Result	Units	Remark
MR-13	Se	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
MR-13	Se	19-Sep-99	Residual Metals	0	ppm	ND
MR-13	Se	25-Aug-99	Sediment Samples	0	ppm	ND
MR-13	Se	25-Aug-99	Sediment Samples	0	ppm	ND
MR-13	Se	25-Aug-99	Sediment Samples	0	ppm	ND
MR-13	Sr	19-Sep-99	Exchangeable Metals	32.9	ppm	000
MR-13	Sr	19-Sep-99	Metals Bound to Carbonates	40.2	ppm	000
MR-13	Sr	19-Sep-99	Metals Bound to Iron and Manganese	16	ppm	000
MR-13	Sr	19-Sep-99	Metals Bound to Organic Matter	2.1	ppm	000
MR-13	Sr	19-Sep-99	Residual Metals	185	ppm	000
MR-13	Sr	25-Aug-99	Sediment Samples	52.1	ppm	000
MR-13	Sr	25-Aug-99	Sediment Samples	40.2	ppm	000
MR-13	Sr	25-Aug-99	Sediment Samples	30.9	ppm	000
MR-13	Ti	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-13	Ti	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
MR-13	Ti	19-Sep-99	Metals Bound to Iron and Manganese	0.5	ppm	000
MR-13	Ti	19-Sep-99	Metals Bound to Organic Matter	2.2	ppm	000
MR-13	Ti	19-Sep-99	Residual Metals	2900	ppm	000
MR-13	Ti	25-Aug-99	Sediment Samples	350	ppm	000
MR-13	Ti	25-Aug-99	Sediment Samples	267	ppm	000
MR-13	Ti	25-Aug-99	Sediment Samples	425	ppm	000
MR-13	V	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
MR-13	V	19-Sep-99	Metals Bound to Carbonates	1.9	ppm	000
MR-13	V	19-Sep-99	Metals Bound to Iron and Manganese	7.3	ppm	000
MR-13	V	19-Sep-99	Metals Bound to Organic Matter	4	ppm	000
MR-13	V	19-Sep-99	Residual Metals	56	ppm	000
MR-13	V	25-Aug-99	Sediment Samples	29	ppm	000
MR-13	V	25-Aug-99	Sediment Samples	27	ppm	000
MR-13	V	25-Aug-99	Sediment Samples	40	ppm	000
MR-13	Zn	19-Sep-99	Exchangeable Metals	1.3	ppm	000
MR-13	Zn	19-Sep-99	Metals Bound to Carbonates	29	ppm	000
MR-13	Zn	19-Sep-99	Metals Bound to Iron and Manganese	93.7	ppm	000
MR-13	Zn	19-Sep-99	Metals Bound to Organic Matter	19	ppm	000
MR-13	Zn	19-Sep-99	Residual Metals	67	ppm	000
MR-13	Zn	25-Aug-99	Sediment Samples	149	ppm	000
MR-13	Zn	25-Aug-99	Sediment Samples	135	ppm	000
MR-13	Zn	25-Aug-99	Sediment Samples	118	ppm	000
ML-1	As	19-Sep-99	Exchangeable Metals	5.2	ppm	000
ML-1	As	19-Sep-99	Metals Bound to Carbonates	52.5	ppm	000
ML-1	As	19-Sep-99	Metals Bound to Iron and Manganese	260	ppm	000
ML-1	As	19-Sep-99	Metals Bound to Organic Matter	37	ppm	000
ML-1	As	19-Sep-99	Residual Metals	110	ppm	000
ML-1	As	25-Aug-99	Sediment Samples	293	ppm	000
ML-1	As	25-Aug-99	Sediment Samples	293	ppm	000
ML-1	As	25-Aug-99	Sediment Samples	274	ppm	000
ML-1	Co	19-Sep-99	Exchangeable Metals	12.4	ppm	000
ML-1	Co	19-Sep-99	Metals Bound to Carbonates	86.8	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
ML-1	Co	19-Sep-99	Metals Bound to Iron and Manganese	384	ppm	000
ML-1	Co	19-Sep-99	Metals Bound to Organic Matter	527	ppm	000
ML-1	Co	19-Sep-99	Residual Metals	30	ppm	000
ML-1	Co	25-Aug-99	Sediment Samples	971	ppm	000
ML-1	Co	25-Aug-99	Sediment Samples	583	ppm	000
ML-1	Co	25-Aug-99	Sediment Samples	199	ppm	000
ML-1	Cu	19-Sep-99	Exchangeable Metals	0.7	ppm	000
ML-1	Cu	19-Sep-99	Metals Bound to Carbonates	1.2	ppm	000
ML-1	Cu	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
ML-1	Cu	19-Sep-99	Metals Bound to Organic Matter	215	ppm	000
ML-1	Cu	19-Sep-99	Residual Metals	20.1	ppm	000
ML-1	Cu	25-Aug-99	Sediment Samples	193	ppm	000
ML-1	Cu	25-Aug-99	Sediment Samples	125	ppm	000
ML-1	Cu	25-Aug-99	Sediment Samples	76	ppm	000
ML-1	Ni	19-Sep-99	Exchangeable Metals	14	ppm	000
ML-1	Ni	19-Sep-99	Metals Bound to Carbonates	63	ppm	000
ML-1	Ni	19-Sep-99	Metals Bound to Iron and Manganese	319	ppm	000
ML-1	Ni	19-Sep-99	Metals Bound to Organic Matter	652	ppm	000
ML-1	Ni	19-Sep-99	Residual Metals	66	ppm	000
ML-1	Ni	25-Aug-99	Sediment Samples	1360	ppm	000
ML-1	Ni	25-Aug-99	Sediment Samples	1030	ppm	000
ML-1	Ni	25-Aug-99	Sediment Samples	370	ppm	000
ML-1	Pb	19-Sep-99	Exchangeable Metals	4	ppm	<=W
ML-1	Pb	19-Sep-99	Metals Bound to Carbonates	11	ppm	000
ML-1	Pb	19-Sep-99	Metals Bound to Iron and Manganese	20	ppm	000
ML-1	Pb	19-Sep-99	Metals Bound to Organic Matter	8	ppm	000
ML-1	Pb	19-Sep-99	Residual Metals	55	ppm	000
ML-1	Pb	25-Aug-99	Sediment Samples	73	ppm	000
ML-1	Pb	25-Aug-99	Sediment Samples	33	ppm	000
ML-1	Pb	25-Aug-99	Sediment Samples	12	ppm	000
ML-1	Hg	19-Sep-99	Exchangeable Metals	0.01	ppm	<=W
ML-1	Hg	19-Sep-99	Metals Bound to Carbonates	0.01	ppm	<=W
ML-1	Hg	19-Sep-99	Metals Bound to Iron and Manganese	0.02	ppm	<=W
ML-1	Hg	19-Sep-99	Metals Bound to Organic Matter	0.02	ppm	<=W
ML-1	Hg	19-Sep-99	Residual Metals	1.88	ppm	000
ML-1	Hg	25-Aug-99	Sediment Samples	1.82	ppm	000
ML-1	Hg	25-Aug-99	Sediment Samples	1.43	ppm	000
ML-1	Hg	25-Aug-99	Sediment Samples	0.66	ppm	000
ML-1	U	19-Sep-99	Exchangeable Metals	0.1	ppm	<=W
ML-1	U	19-Sep-99	Metals Bound to Carbonates	0.4	ppm	000
ML-1	U	19-Sep-99	Metals Bound to Iron and Manganese	0.6	ppm	000
ML-1	U	19-Sep-99	Metals Bound to Organic Matter	0.6	ppm	000
ML-1	U	19-Sep-99	Residual Metals	0.5	ppm	000
ML-1	U	25-Aug-99	Sediment Samples	2.49	ppm	000
ML-1	U	25-Aug-99	Sediment Samples	2.95	ppm	000
ML-1	U	25-Aug-99	Sediment Samples	2.51	ppm	000
ML-1	Ag	19-Sep-99	Exchangeable Metals	0.3	ppm	<=W

Station	Parameter	Date	Description	Result	Units	Remark
ML-1	Ag	19-Sep-99	Metals Bound to Carbonates	0.3	ppm	<=W
ML-1	Ag	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
ML-1	Ag	19-Sep-99	Metals Bound to Organic Matter	0.3	ppm	<=W
ML-1	Ag	19-Sep-99	Residual Metals	16.8	ppm	000
ML-1	Ag	25-Aug-99	Sediment Samples	1.3	ppm	000
ML-1	Ag	25-Aug-99	Sediment Samples	1.5	ppm	000
ML-1	Ag	25-Aug-99	Sediment Samples	3.1	ppm	000
ML-1	Al	19-Sep-99	Exchangeable Metals	3	ppm	<=W
ML-1	Al	19-Sep-99	Metals Bound to Carbonates	51	ppm	000
ML-1	Al	19-Sep-99	Metals Bound to Iron and Manganese	858	ppm	000
ML-1	Al	19-Sep-99	Metals Bound to Organic Matter	4720	ppm	000
ML-1	Al	19-Sep-99	Residual Metals	23800	ppm	000
ML-1	Al	25-Aug-99	Sediment Samples	13100	ppm	000
ML-1	Al	25-Aug-99	Sediment Samples	11400	ppm	000
ML-1	Al	25-Aug-99	Sediment Samples	11200	ppm	000
ML-1	Ba	19-Sep-99	Exchangeable Metals	54.3	ppm	000
ML-1	Ba	19-Sep-99	Metals Bound to Carbonates	69.2	ppm	000
ML-1	Ba	19-Sep-99	Metals Bound to Iron and Manganese	99.3	ppm	000
ML-1	Ba	19-Sep-99	Metals Bound to Organic Matter	8.4	ppm	000
ML-1	Ba	19-Sep-99	Residual Metals	658	ppm	000
ML-1	Ba	25-Aug-99	Sediment Samples	49	ppm	000
ML-1	Ba	25-Aug-99	Sediment Samples	61	ppm	000
ML-1	Ba	25-Aug-99	Sediment Samples	68	ppm	000
ML-1	Be	19-Sep-99	Exchangeable Metals	0.04	ppm	<=W
ML-1	Be	19-Sep-99	Metals Bound to Carbonates	0.06	ppm	000
ML-1	Be	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	000
ML-1	Be	19-Sep-99	Metals Bound to Organic Matter	0.15	ppm	000
ML-1	Be	19-Sep-99	Residual Metals	0.51	ppm	000
ML-1	Be	25-Aug-99	Sediment Samples	0.8	ppm	000
ML-1	Be	25-Aug-99	Sediment Samples	0.8	ppm	000
ML-1	Be	25-Aug-99	Sediment Samples	0.8	ppm	000
ML-1	Bi	19-Sep-99	Exchangeable Metals	8	ppm	<=W
ML-1	Bi	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
ML-1	Bi	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
ML-1	Bi	19-Sep-99	Metals Bound to Organic Matter	21	ppm	000
ML-1	Bi	19-Sep-99	Residual Metals	0	ppm	ND
ML-1	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
ML-1	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
ML-1	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
ML-1	Ca	19-Sep-99	Exchangeable Metals	8980	ppm	000
ML-1	Ca	19-Sep-99	Metals Bound to Carbonates	10900	ppm	000
ML-1	Ca	19-Sep-99	Metals Bound to Iron and Manganese	8720	ppm	000
ML-1	Ca	19-Sep-99	Metals Bound to Organic Matter	2750	ppm	000
ML-1	Ca	19-Sep-99	Residual Metals	3650	ppm	000
ML-1	Ca	25-Aug-99	Sediment Samples	27800	ppm	000
ML-1	Ca	25-Aug-99	Sediment Samples	24700	ppm	000
ML-1	Ca	25-Aug-99	Sediment Samples	24400	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
ML-1	Cd	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
ML-1	Cd	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
ML-1	Cd	19-Sep-99	Metals Bound to Iron and Manganese	2.3	ppm	000
ML-1	Cd	19-Sep-99	Metals Bound to Organic Matter	1	ppm	000
ML-1	Cd	19-Sep-99	Residual Metals	0.1	ppm	<=W
ML-1	Cd	25-Aug-99	Sediment Samples	2	ppm	000
ML-1	Cd	25-Aug-99	Sediment Samples	1.4	ppm	000
ML-1	Cd	25-Aug-99	Sediment Samples	1	ppm	000
ML-1	Cr	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
ML-1	Cr	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
ML-1	Cr	19-Sep-99	Metals Bound to Iron and Manganese	1.5	ppm	000
ML-1	Cr	19-Sep-99	Metals Bound to Organic Matter	19	ppm	000
ML-1	Cr	19-Sep-99	Residual Metals	26	ppm	000
ML-1	Cr	25-Aug-99	Sediment Samples	32	ppm	000
ML-1	Cr	25-Aug-99	Sediment Samples	27	ppm	000
ML-1	Cr	25-Aug-99	Sediment Samples	27	ppm	000
ML-1	Fe	19-Sep-99	Exchangeable Metals	4	ppm	000
ML-1	Fe	19-Sep-99	Metals Bound to Carbonates	287	ppm	000
ML-1	Fe	19-Sep-99	Metals Bound to Iron and Manganese	11300	ppm	000
ML-1	Fe	19-Sep-99	Metals Bound to Organic Matter	9770	ppm	000
ML-1	Fe	19-Sep-99	Residual Metals	13500	ppm	000
ML-1	Fe	25-Aug-99	Sediment Samples	28100	ppm	000
ML-1	Fe	25-Aug-99	Sediment Samples	24100	ppm	000
ML-1	Fe	25-Aug-99	Sediment Samples	23400	ppm	000
ML-1	K	19-Sep-99	Exchangeable Metals	226	ppm	000
ML-1	K	19-Sep-99	Metals Bound to Carbonates	80	ppm	<=W
ML-1	K	19-Sep-99	Metals Bound to Iron and Manganese	100	ppm	<=W
ML-1	K	19-Sep-99	Metals Bound to Organic Matter	100	ppm	<=W
ML-1	K	19-Sep-99	Residual Metals	8860	ppm	000
ML-1	K	25-Aug-99	Sediment Samples	1830	ppm	000
ML-1	K	25-Aug-99	Sediment Samples	1280	ppm	000
ML-1	K	25-Aug-99	Sediment Samples	1010	ppm	000
ML-1	Mg	19-Sep-99	Exchangeable Metals	474	ppm	000
ML-1	Mg	19-Sep-99	Metals Bound to Carbonates	222	ppm	000
ML-1	Mg	19-Sep-99	Metals Bound to Iron and Manganese	1450	ppm	000
ML-1	Mg	19-Sep-99	Metals Bound to Organic Matter	1590	ppm	000
ML-1	Mg	19-Sep-99	Residual Metals	5010	ppm	000
ML-1	Mg	25-Aug-99	Sediment Samples	6520	ppm	000
ML-1	Mg	25-Aug-99	Sediment Samples	6020	ppm	000
ML-1	Mg	25-Aug-99	Sediment Samples	6030	ppm	000
ML-1	Mn	19-Sep-99	Exchangeable Metals	188	ppm	000
ML-1	Mn	19-Sep-99	Metals Bound to Carbonates	301	ppm	000
ML-1	Mn	19-Sep-99	Metals Bound to Iron and Manganese	284	ppm	000
ML-1	Mn	19-Sep-99	Metals Bound to Organic Matter	68.3	ppm	000
ML-1	Mn	19-Sep-99	Residual Metals	95	ppm	000
ML-1	Mn	25-Aug-99	Sediment Samples	643	ppm	000
ML-1	Mn	25-Aug-99	Sediment Samples	547	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
ML-1	Mn	25-Aug-99	Sediment Samples	447	ppm	000
ML-1	Mo	19-Sep-99	Exchangeable Metals	2	ppm	<=W
ML-1	Mo	19-Sep-99	Metals Bound to Carbonates	1	ppm	<=W
ML-1	Mo	19-Sep-99	Metals Bound to Iron and Manganese	2	ppm	<=W
ML-1	Mo	19-Sep-99	Metals Bound to Organic Matter	2	ppm	<=W
ML-1	Mo	19-Sep-99	Residual Metals	5	ppm	<=W
ML-1	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
ML-1	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
ML-1	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
ML-1	Na	19-Sep-99	Exchangeable Metals	0	ppm	ND
ML-1	Na	19-Sep-99	Metals Bound to Carbonates	0	ppm	ND
ML-1	Na	19-Sep-99	Metals Bound to Iron and Manganese	0	ppm	ND
ML-1	Na	19-Sep-99	Metals Bound to Organic Matter	0	ppm	ND
ML-1	Na	19-Sep-99	Residual Metals	0	ppm	ND
ML-1	Na	25-Aug-99	Sediment Samples	243	ppm	000
ML-1	Na	25-Aug-99	Sediment Samples	193	ppm	000
ML-1	Na	25-Aug-99	Sediment Samples	196	ppm	000
ML-1	P	19-Sep-99	Exchangeable Metals	8	ppm	<=W
ML-1	P	19-Sep-99	Metals Bound to Carbonates	19	ppm	000
ML-1	P	19-Sep-99	Metals Bound to Iron and Manganese	250	ppm	000
ML-1	P	19-Sep-99	Metals Bound to Organic Matter	221	ppm	000
ML-1	P	19-Sep-99	Residual Metals	950	ppm	000
ML-1	P	25-Aug-99	Sediment Samples	1150	ppm	000
ML-1	P	25-Aug-99	Sediment Samples	1060	ppm	000
ML-1	P	25-Aug-99	Sediment Samples	1040	ppm	000
ML-1	S	19-Sep-99	Exchangeable Metals	524	ppm	000
ML-1	S	19-Sep-99	Metals Bound to Carbonates	132	ppm	000
ML-1	S	19-Sep-99	Metals Bound to Iron and Manganese	1250	ppm	000
ML-1	S	19-Sep-99	Metals Bound to Organic Matter	12900	ppm	000
ML-1	S	19-Sep-99	Residual Metals	0	ppm	ND
ML-1	S	25-Aug-99	Sediment Samples	0	ppm	ND
ML-1	S	25-Aug-99	Sediment Samples	0	ppm	ND
ML-1	S	25-Aug-99	Sediment Samples	0	ppm	ND
ML-1	Sb	19-Sep-99	Exchangeable Metals	8	ppm	<=W
ML-1	Sb	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
ML-1	Sb	19-Sep-99	Metals Bound to Iron and Manganese	65	ppm	000
ML-1	Sb	19-Sep-99	Metals Bound to Organic Matter	63	ppm	000
ML-1	Sb	19-Sep-99	Residual Metals	0	ppm	ND
ML-1	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
ML-1	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
ML-1	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
ML-1	Se	19-Sep-99	Exchangeable Metals	8	ppm	<=W
ML-1	Se	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
ML-1	Se	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
ML-1	Se	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
ML-1	Se	19-Sep-99	Residual Metals	0	ppm	ND
ML-1	Se	25-Aug-99	Sediment Samples	0	ppm	ND

Station	Parameter	Date	Description	Result	Units	Remark
ML-1	Se	25-Aug-99	Sediment Samples	0	ppm	ND
ML-1	Se	25-Aug-99	Sediment Samples	0	ppm	ND
ML-1	Sr	19-Sep-99	Exchangeable Metals	70.7	ppm	000
ML-1	Sr	19-Sep-99	Metals Bound to Carbonates	69.7	ppm	000
ML-1	Sr	19-Sep-99	Metals Bound to Iron and Manganese	56.2	ppm	000
ML-1	Sr	19-Sep-99	Metals Bound to Organic Matter	14.3	ppm	000
ML-1	Sr	19-Sep-99	Residual Metals	81	ppm	000
ML-1	Sr	25-Aug-99	Sediment Samples	192	ppm	000
ML-1	Sr	25-Aug-99	Sediment Samples	179	ppm	000
ML-1	Sr	25-Aug-99	Sediment Samples	201	ppm	000
ML-1	Ti	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
ML-1	Ti	19-Sep-99	Metals Bound to Carbonates	0.7	ppm	000
ML-1	Ti	19-Sep-99	Metals Bound to Iron and Manganese	0.9	ppm	000
ML-1	Ti	19-Sep-99	Metals Bound to Organic Matter	14.1	ppm	000
ML-1	Ti	19-Sep-99	Residual Metals	1620	ppm	000
ML-1	Ti	25-Aug-99	Sediment Samples	459	ppm	000
ML-1	Ti	25-Aug-99	Sediment Samples	341	ppm	000
ML-1	Ti	25-Aug-99	Sediment Samples	289	ppm	000
ML-1	V	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
ML-1	V	19-Sep-99	Metals Bound to Carbonates	1.2	ppm	000
ML-1	V	19-Sep-99	Metals Bound to Iron and Manganese	5.5	ppm	000
ML-1	V	19-Sep-99	Metals Bound to Organic Matter	16.2	ppm	000
ML-1	V	19-Sep-99	Residual Metals	30	ppm	000
ML-1	V	25-Aug-99	Sediment Samples	35	ppm	000
ML-1	V	25-Aug-99	Sediment Samples	34	ppm	000
ML-1	V	25-Aug-99	Sediment Samples	34	ppm	000
ML-1	Zn	19-Sep-99	Exchangeable Metals	1.3	ppm	000
ML-1	Zn	19-Sep-99	Metals Bound to Carbonates	40.1	ppm	000
ML-1	Zn	19-Sep-99	Metals Bound to Iron and Manganese	247	ppm	000
ML-1	Zn	19-Sep-99	Metals Bound to Organic Matter	128	ppm	000
ML-1	Zn	19-Sep-99	Residual Metals	36	ppm	000
ML-1	Zn	25-Aug-99	Sediment Samples	414	ppm	000
ML-1	Zn	25-Aug-99	Sediment Samples	326	ppm	000
ML-1	Zn	25-Aug-99	Sediment Samples	276	ppm	000
ML-3	As	19-Sep-99	Exchangeable Metals	3.4	ppm	000
ML-3	As	19-Sep-99	Metals Bound to Carbonates	31.9	ppm	000
ML-3	As	19-Sep-99	Metals Bound to Iron and Manganese	260	ppm	000
ML-3	As	19-Sep-99	Metals Bound to Organic Matter	83.8	ppm	000
ML-3	As	19-Sep-99	Residual Metals	270	ppm	000
ML-3	As	25-Aug-99	Sediment Samples	852	ppm	000
ML-3	As	25-Aug-99	Sediment Samples	852	ppm	000
ML-3	As	25-Aug-99	Sediment Samples	1040	ppm	000
ML-3	Co	19-Sep-99	Exchangeable Metals	38.6	ppm	000
ML-3	Co	19-Sep-99	Metals Bound to Carbonates	149	ppm	000
ML-3	Co	19-Sep-99	Metals Bound to Iron and Manganese	262	ppm	000
ML-3	Co	19-Sep-99	Metals Bound to Organic Matter	154	ppm	000
ML-3	Co	19-Sep-99	Residual Metals	18	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
ML-3	Co	25-Aug-99	Sediment Samples	694	ppm	000
ML-3	Co	25-Aug-99	Sediment Samples	1380	ppm	000
ML-3	Co	25-Aug-99	Sediment Samples	1160	ppm	000
ML-3	Cu	19-Sep-99	Exchangeable Metals	1.2	ppm	000
ML-3	Cu	19-Sep-99	Metals Bound to Carbonates	1	ppm	000
ML-3	Cu	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
ML-3	Cu	19-Sep-99	Metals Bound to Organic Matter	108	ppm	000
ML-3	Cu	19-Sep-99	Residual Metals	11.8	ppm	000
ML-3	Cu	25-Aug-99	Sediment Samples	133	ppm	000
ML-3	Cu	25-Aug-99	Sediment Samples	197	ppm	000
ML-3	Cu	25-Aug-99	Sediment Samples	193	ppm	000
ML-3	Ni	19-Sep-99	Exchangeable Metals	17	ppm	000
ML-3	Ni	19-Sep-99	Metals Bound to Carbonates	72	ppm	000
ML-3	Ni	19-Sep-99	Metals Bound to Iron and Manganese	151	ppm	000
ML-3	Ni	19-Sep-99	Metals Bound to Organic Matter	120	ppm	000
ML-3	Ni	19-Sep-99	Residual Metals	27	ppm	000
ML-3	Ni	25-Aug-99	Sediment Samples	430	ppm	000
ML-3	Ni	25-Aug-99	Sediment Samples	1560	ppm	000
ML-3	Ni	25-Aug-99	Sediment Samples	933	ppm	000
ML-3	Pb	19-Sep-99	Exchangeable Metals	4	ppm	<=W
ML-3	Pb	19-Sep-99	Metals Bound to Carbonates	12	ppm	000
ML-3	Pb	19-Sep-99	Metals Bound to Iron and Manganese	41	ppm	000
ML-3	Pb	19-Sep-99	Metals Bound to Organic Matter	20	ppm	000
ML-3	Pb	19-Sep-99	Residual Metals	43	ppm	000
ML-3	Pb	25-Aug-99	Sediment Samples	118	ppm	000
ML-3	Pb	25-Aug-99	Sediment Samples	96	ppm	000
ML-3	Pb	25-Aug-99	Sediment Samples	124	ppm	000
ML-3	Hg	19-Sep-99	Exchangeable Metals	0.01	ppm	<=W
ML-3	Hg	19-Sep-99	Metals Bound to Carbonates	0.01	ppm	<=W
ML-3	Hg	19-Sep-99	Metals Bound to Iron and Manganese	0.02	ppm	<=W
ML-3	Hg	19-Sep-99	Metals Bound to Organic Matter	0.02	ppm	<=W
ML-3	Hg	19-Sep-99	Residual Metals	0.65	ppm	000
ML-3	Hg	25-Aug-99	Sediment Samples	0.8	ppm	000
ML-3	Hg	25-Aug-99	Sediment Samples	1.43	ppm	000
ML-3	Hg	25-Aug-99	Sediment Samples	1.12	ppm	000
ML-3	U	19-Sep-99	Exchangeable Metals	0.3	ppm	000
ML-3	U	19-Sep-99	Metals Bound to Carbonates	0.9	ppm	000
ML-3	U	19-Sep-99	Metals Bound to Iron and Manganese	0.8	ppm	000
ML-3	U	19-Sep-99	Metals Bound to Organic Matter	0.3	ppm	000
ML-3	U	19-Sep-99	Residual Metals	0.4	ppm	000
ML-3	U	25-Aug-99	Sediment Samples	2.06	ppm	000
ML-3	U	25-Aug-99	Sediment Samples	1.92	ppm	000
ML-3	U	25-Aug-99	Sediment Samples	1.48	ppm	000
ML-3	Ag	19-Sep-99	Exchangeable Metals	0.3	ppm	<=W
ML-3	Ag	19-Sep-99	Metals Bound to Carbonates	0.3	ppm	<=W
ML-3	Ag	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
ML-3	Ag	19-Sep-99	Metals Bound to Organic Matter	0.3	ppm	<=W

Station	Parameter	Date	Description	Result	Units	Remark
ML-3	Ag	19-Sep-99	Residual Metals	4.4	ppm	000
ML-3	Ag	25-Aug-99	Sediment Samples	6.2	ppm	000
ML-3	Ag	25-Aug-99	Sediment Samples	3	ppm	000
ML-3	Ag	25-Aug-99	Sediment Samples	2	ppm	000
ML-3	Al	19-Sep-99	Exchangeable Metals	3	ppm	000
ML-3	Al	19-Sep-99	Metals Bound to Carbonates	25	ppm	000
ML-3	Al	19-Sep-99	Metals Bound to Iron and Manganese	616	ppm	000
ML-3	Al	19-Sep-99	Metals Bound to Organic Matter	2060	ppm	000
ML-3	Al	19-Sep-99	Residual Metals	18600	ppm	000
ML-3	Al	25-Aug-99	Sediment Samples	8340	ppm	000
ML-3	Al	25-Aug-99	Sediment Samples	13900	ppm	000
ML-3	Al	25-Aug-99	Sediment Samples	12400	ppm	000
ML-3	Ba	19-Sep-99	Exchangeable Metals	42.8	ppm	000
ML-3	Ba	19-Sep-99	Metals Bound to Carbonates	76.4	ppm	000
ML-3	Ba	19-Sep-99	Metals Bound to Iron and Manganese	86.9	ppm	000
ML-3	Ba	19-Sep-99	Metals Bound to Organic Matter	6.9	ppm	000
ML-3	Ba	19-Sep-99	Residual Metals	229	ppm	000
ML-3	Ba	25-Aug-99	Sediment Samples	61	ppm	000
ML-3	Ba	25-Aug-99	Sediment Samples	39	ppm	000
ML-3	Ba	25-Aug-99	Sediment Samples	42	ppm	000
ML-3	Be	19-Sep-99	Exchangeable Metals	0.04	ppm	<=W
ML-3	Be	19-Sep-99	Metals Bound to Carbonates	0.06	ppm	000
ML-3	Be	19-Sep-99	Metals Bound to Iron and Manganese	0.26	ppm	000
ML-3	Be	19-Sep-99	Metals Bound to Organic Matter	0.11	ppm	000
ML-3	Be	19-Sep-99	Residual Metals	0.43	ppm	000
ML-3	Be	25-Aug-99	Sediment Samples	0.6	ppm	000
ML-3	Be	25-Aug-99	Sediment Samples	0.9	ppm	000
ML-3	Be	25-Aug-99	Sediment Samples	0.8	ppm	000
ML-3	Bi	19-Sep-99	Exchangeable Metals	8	ppm	<=W
ML-3	Bi	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
ML-3	Bi	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
ML-3	Bi	19-Sep-99	Metals Bound to Organic Matter	14	ppm	000
ML-3	Bi	19-Sep-99	Residual Metals	0	ppm	ND
ML-3	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
ML-3	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
ML-3	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
ML-3	Ca	19-Sep-99	Exchangeable Metals	8390	ppm	000
ML-3	Ca	19-Sep-99	Metals Bound to Carbonates	23600	ppm	000
ML-3	Ca	19-Sep-99	Metals Bound to Iron and Manganese	11700	ppm	000
ML-3	Ca	19-Sep-99	Metals Bound to Organic Matter	2410	ppm	000
ML-3	Ca	19-Sep-99	Residual Metals	2470	ppm	000
ML-3	Ca	25-Aug-99	Sediment Samples	40400	ppm	000
ML-3	Ca	25-Aug-99	Sediment Samples	20400	ppm	000
ML-3	Ca	25-Aug-99	Sediment Samples	31500	ppm	000
ML-3	Cd	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
ML-3	Cd	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
ML-3	Cd	19-Sep-99	Metals Bound to Iron and Manganese	1.2	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
ML-3	Cd	19-Sep-99	Metals Bound to Organic Matter	0.5	ppm	<=W
ML-3	Cd	19-Sep-99	Residual Metals	0.1	ppm	<=W
ML-3	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
ML-3	Cd	25-Aug-99	Sediment Samples	1.3	ppm	000
ML-3	Cd	25-Aug-99	Sediment Samples	0.7	ppm	000
ML-3	Cr	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
ML-3	Cr	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
ML-3	Cr	19-Sep-99	Metals Bound to Iron and Manganese	4.3	ppm	000
ML-3	Cr	19-Sep-99	Metals Bound to Organic Matter	6.6	ppm	000
ML-3	Cr	19-Sep-99	Residual Metals	23	ppm	000
ML-3	Cr	25-Aug-99	Sediment Samples	22	ppm	000
ML-3	Cr	25-Aug-99	Sediment Samples	29	ppm	000
ML-3	Cr	25-Aug-99	Sediment Samples	30	ppm	000
ML-3	Fe	19-Sep-99	Exchangeable Metals	5	ppm	000
ML-3	Fe	19-Sep-99	Metals Bound to Carbonates	1170	ppm	000
ML-3	Fe	19-Sep-99	Metals Bound to Iron and Manganese	15100	ppm	000
ML-3	Fe	19-Sep-99	Metals Bound to Organic Matter	9060	ppm	000
ML-3	Fe	19-Sep-99	Residual Metals	12000	ppm	000
ML-3	Fe	25-Aug-99	Sediment Samples	33600	ppm	000
ML-3	Fe	25-Aug-99	Sediment Samples	32500	ppm	000
ML-3	Fe	25-Aug-99	Sediment Samples	35100	ppm	000
ML-3	K	19-Sep-99	Exchangeable Metals	313	ppm	000
ML-3	K	19-Sep-99	Metals Bound to Carbonates	80	ppm	<=W
ML-3	K	19-Sep-99	Metals Bound to Iron and Manganese	100	ppm	<=W
ML-3	K	19-Sep-99	Metals Bound to Organic Matter	100	ppm	<=W
ML-3	K	19-Sep-99	Residual Metals	7360	ppm	000
ML-3	K	25-Aug-99	Sediment Samples	1220	ppm	000
ML-3	K	25-Aug-99	Sediment Samples	1800	ppm	000
ML-3	K	25-Aug-99	Sediment Samples	1840	ppm	000
ML-3	Mg	19-Sep-99	Exchangeable Metals	440	ppm	000
ML-3	Mg	19-Sep-99	Metals Bound to Carbonates	228	ppm	000
ML-3	Mg	19-Sep-99	Metals Bound to Iron and Manganese	1710	ppm	000
ML-3	Mg	19-Sep-99	Metals Bound to Organic Matter	1070	ppm	000
ML-3	Mg	19-Sep-99	Residual Metals	4650	ppm	000
ML-3	Mg	25-Aug-99	Sediment Samples	5330	ppm	000
ML-3	Mg	25-Aug-99	Sediment Samples	7160	ppm	000
ML-3	Mg	25-Aug-99	Sediment Samples	6650	ppm	000
ML-3	Mn	19-Sep-99	Exchangeable Metals	113	ppm	000
ML-3	Mn	19-Sep-99	Metals Bound to Carbonates	209	ppm	000
ML-3	Mn	19-Sep-99	Metals Bound to Iron and Manganese	204	ppm	000
ML-3	Mn	19-Sep-99	Metals Bound to Organic Matter	39.7	ppm	000
ML-3	Mn	19-Sep-99	Residual Metals	81	ppm	000
ML-3	Mn	25-Aug-99	Sediment Samples	477	ppm	000
ML-3	Mn	25-Aug-99	Sediment Samples	457	ppm	000
ML-3	Mn	25-Aug-99	Sediment Samples	445	ppm	000
ML-3	Mo	19-Sep-99	Exchangeable Metals	2	ppm	<=W
ML-3	Mo	19-Sep-99	Metals Bound to Carbonates	1	ppm	<=W

Station	Parameter	Date	Description	Result	Units	Remark
ML-3	Mo	19-Sep-99	Metals Bound to Iron and Manganese	2	ppm	<=W
ML-3	Mo	19-Sep-99	Metals Bound to Organic Matter	2	ppm	<=W
ML-3	Mo	19-Sep-99	Residual Metals	5	ppm	<=W
ML-3	Mo	25-Aug-99	Sediment Samples	4	ppm	000
ML-3	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
ML-3	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
ML-3	Na	19-Sep-99	Exchangeable Metals	0	ppm	ND
ML-3	Na	19-Sep-99	Metals Bound to Carbonates	0	ppm	ND
ML-3	Na	19-Sep-99	Metals Bound to Iron and Manganese	0	ppm	ND
ML-3	Na	19-Sep-99	Metals Bound to Organic Matter	0	ppm	ND
ML-3	Na	19-Sep-99	Residual Metals	0	ppm	ND
ML-3	Na	25-Aug-99	Sediment Samples	199	ppm	000
ML-3	Na	25-Aug-99	Sediment Samples	208	ppm	000
ML-3	Na	25-Aug-99	Sediment Samples	205	ppm	000
ML-3	P	19-Sep-99	Exchangeable Metals	26	ppm	000
ML-3	P	19-Sep-99	Metals Bound to Carbonates	37	ppm	000
ML-3	P	19-Sep-99	Metals Bound to Iron and Manganese	237	ppm	000
ML-3	P	19-Sep-99	Metals Bound to Organic Matter	263	ppm	000
ML-3	P	19-Sep-99	Residual Metals	860	ppm	000
ML-3	P	25-Aug-99	Sediment Samples	1080	ppm	000
ML-3	P	25-Aug-99	Sediment Samples	1060	ppm	000
ML-3	P	25-Aug-99	Sediment Samples	1020	ppm	000
ML-3	S	19-Sep-99	Exchangeable Metals	2040	ppm	000
ML-3	S	19-Sep-99	Metals Bound to Carbonates	409	ppm	000
ML-3	S	19-Sep-99	Metals Bound to Iron and Manganese	1250	ppm	000
ML-3	S	19-Sep-99	Metals Bound to Organic Matter	15300	ppm	000
ML-3	S	19-Sep-99	Residual Metals	0	ppm	ND
ML-3	S	25-Aug-99	Sediment Samples	0	ppm	ND
ML-3	S	25-Aug-99	Sediment Samples	0	ppm	ND
ML-3	S	25-Aug-99	Sediment Samples	0	ppm	ND
ML-3	Sb	19-Sep-99	Exchangeable Metals	8	ppm	<=W
ML-3	Sb	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
ML-3	Sb	19-Sep-99	Metals Bound to Iron and Manganese	92	ppm	000
ML-3	Sb	19-Sep-99	Metals Bound to Organic Matter	57	ppm	000
ML-3	Sb	19-Sep-99	Residual Metals	0	ppm	ND
ML-3	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
ML-3	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
ML-3	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
ML-3	Se	19-Sep-99	Exchangeable Metals	8	ppm	<=W
ML-3	Se	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
ML-3	Se	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
ML-3	Se	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
ML-3	Se	19-Sep-99	Residual Metals	0	ppm	ND
ML-3	Se	25-Aug-99	Sediment Samples	0	ppm	ND
ML-3	Se	25-Aug-99	Sediment Samples	0	ppm	ND
ML-3	Se	25-Aug-99	Sediment Samples	0	ppm	ND
ML-3	Sr	19-Sep-99	Exchangeable Metals	60.1	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
ML-3	Sr	19-Sep-99	Metals Bound to Carbonates	87.8	ppm	000
ML-3	Sr	19-Sep-99	Metals Bound to Iron and Manganese	46.1	ppm	000
ML-3	Sr	19-Sep-99	Metals Bound to Organic Matter	7.2	ppm	000
ML-3	Sr	19-Sep-99	Residual Metals	46	ppm	000
ML-3	Sr	25-Aug-99	Sediment Samples	166	ppm	000
ML-3	Sr	25-Aug-99	Sediment Samples	126	ppm	000
ML-3	Sr	25-Aug-99	Sediment Samples	160	ppm	000
ML-3	Ti	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
ML-3	Ti	19-Sep-99	Metals Bound to Carbonates	0.7	ppm	000
ML-3	Ti	19-Sep-99	Metals Bound to Iron and Manganese	1	ppm	000
ML-3	Ti	19-Sep-99	Metals Bound to Organic Matter	3.8	ppm	000
ML-3	Ti	19-Sep-99	Residual Metals	1110	ppm	000
ML-3	Ti	25-Aug-99	Sediment Samples	204	ppm	000
ML-3	Ti	25-Aug-99	Sediment Samples	313	ppm	000
ML-3	Ti	25-Aug-99	Sediment Samples	308	ppm	000
ML-3	V	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
ML-3	V	19-Sep-99	Metals Bound to Carbonates	1.6	ppm	000
ML-3	V	19-Sep-99	Metals Bound to Iron and Manganese	11.9	ppm	000
ML-3	V	19-Sep-99	Metals Bound to Organic Matter	9.2	ppm	000
ML-3	V	19-Sep-99	Residual Metals	25	ppm	000
ML-3	V	25-Aug-99	Sediment Samples	30	ppm	000
ML-3	V	25-Aug-99	Sediment Samples	37	ppm	000
ML-3	V	25-Aug-99	Sediment Samples	33	ppm	000
ML-3	Zn	19-Sep-99	Exchangeable Metals	1	ppm	000
ML-3	Zn	19-Sep-99	Metals Bound to Carbonates	30.8	ppm	000
ML-3	Zn	19-Sep-99	Metals Bound to Iron and Manganese	116	ppm	000
ML-3	Zn	19-Sep-99	Metals Bound to Organic Matter	33.4	ppm	000
ML-3	Zn	19-Sep-99	Residual Metals	29	ppm	000
ML-3	Zn	25-Aug-99	Sediment Samples	215	ppm	000
ML-3	Zn	25-Aug-99	Sediment Samples	289	ppm	000
ML-3	Zn	25-Aug-99	Sediment Samples	288	ppm	000
ML-4	As	19-Sep-99	Exchangeable Metals	2.9	ppm	000
ML-4	As	19-Sep-99	Metals Bound to Carbonates	27.8	ppm	000
ML-4	As	19-Sep-99	Metals Bound to Iron and Manganese	194	ppm	000
ML-4	As	19-Sep-99	Metals Bound to Organic Matter	26.2	ppm	000
ML-4	As	19-Sep-99	Residual Metals	181	ppm	000
ML-4	As	25-Aug-99	Sediment Samples	475	ppm	000
ML-4	As	25-Aug-99	Sediment Samples	274	ppm	000
ML-4	As	25-Aug-99	Sediment Samples	156	ppm	000
ML-4	Co	19-Sep-99	Exchangeable Metals	14.4	ppm	000
ML-4	Co	19-Sep-99	Metals Bound to Carbonates	107	ppm	000
ML-4	Co	19-Sep-99	Metals Bound to Iron and Manganese	476	ppm	000
ML-4	Co	19-Sep-99	Metals Bound to Organic Matter	376	ppm	000
ML-4	Co	19-Sep-99	Residual Metals	35	ppm	000
ML-4	Co	25-Aug-99	Sediment Samples	1020	ppm	000
ML-4	Co	25-Aug-99	Sediment Samples	589	ppm	000
ML-4	Co	25-Aug-99	Sediment Samples	184	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
ML-4	Cu	19-Sep-99	Exchangeable Metals	0.7	ppm	000
ML-4	Cu	19-Sep-99	Metals Bound to Carbonates	0.7	ppm	000
ML-4	Cu	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
ML-4	Cu	19-Sep-99	Metals Bound to Organic Matter	139	ppm	000
ML-4	Cu	19-Sep-99	Residual Metals	17.3	ppm	000
ML-4	Cu	25-Aug-99	Sediment Samples	141	ppm	000
ML-4	Cu	25-Aug-99	Sediment Samples	61	ppm	000
ML-4	Cu	25-Aug-99	Sediment Samples	25	ppm	000
ML-4	Ni	19-Sep-99	Exchangeable Metals	17	ppm	000
ML-4	Ni	19-Sep-99	Metals Bound to Carbonates	71	ppm	000
ML-4	Ni	19-Sep-99	Metals Bound to Iron and Manganese	311	ppm	000
ML-4	Ni	19-Sep-99	Metals Bound to Organic Matter	284	ppm	000
ML-4	Ni	19-Sep-99	Residual Metals	38	ppm	000
ML-4	Ni	25-Aug-99	Sediment Samples	853	ppm	000
ML-4	Ni	25-Aug-99	Sediment Samples	732	ppm	000
ML-4	Ni	25-Aug-99	Sediment Samples	310	ppm	000
ML-4	Pb	19-Sep-99	Exchangeable Metals	4	ppm	<=W
ML-4	Pb	19-Sep-99	Metals Bound to Carbonates	14	ppm	000
ML-4	Pb	19-Sep-99	Metals Bound to Iron and Manganese	28	ppm	000
ML-4	Pb	19-Sep-99	Metals Bound to Organic Matter	10	ppm	000
ML-4	Pb	19-Sep-99	Residual Metals	50	ppm	000
ML-4	Pb	25-Aug-99	Sediment Samples	88	ppm	000
ML-4	Pb	25-Aug-99	Sediment Samples	30	ppm	000
ML-4	Pb	25-Aug-99	Sediment Samples	14	ppm	000
ML-4	Hg	19-Sep-99	Exchangeable Metals	0.01	ppm	<=W
ML-4	Hg	19-Sep-99	Metals Bound to Carbonates	0.01	ppm	<=W
ML-4	Hg	19-Sep-99	Metals Bound to Iron and Manganese	0.02	ppm	<=W
ML-4	Hg	19-Sep-99	Metals Bound to Organic Matter	0.02	ppm	<=W
ML-4	Hg	19-Sep-99	Residual Metals	0.95	ppm	000
ML-4	Hg	25-Aug-99	Sediment Samples	0.97	ppm	000
ML-4	Hg	25-Aug-99	Sediment Samples	0.46	ppm	000
ML-4	Hg	25-Aug-99	Sediment Samples	0.22	ppm	000
ML-4	U	19-Sep-99	Exchangeable Metals	0.1	ppm	000
ML-4	U	19-Sep-99	Metals Bound to Carbonates	0.6	ppm	000
ML-4	U	19-Sep-99	Metals Bound to Iron and Manganese	0.6	ppm	000
ML-4	U	19-Sep-99	Metals Bound to Organic Matter	0.4	ppm	000
ML-4	U	19-Sep-99	Residual Metals	0.7	ppm	000
ML-4	U	25-Aug-99	Sediment Samples	1.64	ppm	000
ML-4	U	25-Aug-99	Sediment Samples	1.04	ppm	000
ML-4	U	25-Aug-99	Sediment Samples	0.78	ppm	000
ML-4	Ag	19-Sep-99	Exchangeable Metals	0.3	ppm	<=W
ML-4	Ag	19-Sep-99	Metals Bound to Carbonates	0.3	ppm	<=W
ML-4	Ag	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
ML-4	Ag	19-Sep-99	Metals Bound to Organic Matter	0.3	ppm	<=W
ML-4	Ag	19-Sep-99	Residual Metals	5.3	ppm	000
ML-4	Ag	25-Aug-99	Sediment Samples	1.2	ppm	000
ML-4	Ag	25-Aug-99	Sediment Samples	3.3	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
ML-4	Ag	25-Aug-99	Sediment Samples	1	ppm	000
ML-4	Al	19-Sep-99	Exchangeable Metals	4	ppm	000
ML-4	Al	19-Sep-99	Metals Bound to Carbonates	40	ppm	000
ML-4	Al	19-Sep-99	Metals Bound to Iron and Manganese	724	ppm	000
ML-4	Al	19-Sep-99	Metals Bound to Organic Matter	3080	ppm	000
ML-4	Al	19-Sep-99	Residual Metals	30300	ppm	000
ML-4	Al	25-Aug-99	Sediment Samples	11400	ppm	000
ML-4	Al	25-Aug-99	Sediment Samples	9310	ppm	000
ML-4	Al	25-Aug-99	Sediment Samples	5710	ppm	000
ML-4	Ba	19-Sep-99	Exchangeable Metals	44.7	ppm	000
ML-4	Ba	19-Sep-99	Metals Bound to Carbonates	72.6	ppm	000
ML-4	Ba	19-Sep-99	Metals Bound to Iron and Manganese	93.2	ppm	000
ML-4	Ba	19-Sep-99	Metals Bound to Organic Matter	10.1	ppm	000
ML-4	Ba	19-Sep-99	Residual Metals	289	ppm	000
ML-4	Ba	25-Aug-99	Sediment Samples	37	ppm	000
ML-4	Ba	25-Aug-99	Sediment Samples	136	ppm	000
ML-4	Ba	25-Aug-99	Sediment Samples	198	ppm	000
ML-4	Be	19-Sep-99	Exchangeable Metals	0.04	ppm	<=W
ML-4	Be	19-Sep-99	Metals Bound to Carbonates	0.06	ppm	000
ML-4	Be	19-Sep-99	Metals Bound to Iron and Manganese	0.32	ppm	000
ML-4	Be	19-Sep-99	Metals Bound to Organic Matter	0.09	ppm	000
ML-4	Be	19-Sep-99	Residual Metals	0.66	ppm	000
ML-4	Be	25-Aug-99	Sediment Samples	0.8	ppm	000
ML-4	Be	25-Aug-99	Sediment Samples	0.7	ppm	000
ML-4	Be	25-Aug-99	Sediment Samples	0.6	ppm	000
ML-4	Bi	19-Sep-99	Exchangeable Metals	8	ppm	<=W
ML-4	Bi	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
ML-4	Bi	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
ML-4	Bi	19-Sep-99	Metals Bound to Organic Matter	20	ppm	000
ML-4	Bi	19-Sep-99	Residual Metals	0	ppm	ND
ML-4	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
ML-4	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
ML-4	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
ML-4	Ca	19-Sep-99	Exchangeable Metals	6900	ppm	000
ML-4	Ca	19-Sep-99	Metals Bound to Carbonates	11100	ppm	000
ML-4	Ca	19-Sep-99	Metals Bound to Iron and Manganese	6650	ppm	000
ML-4	Ca	19-Sep-99	Metals Bound to Organic Matter	1230	ppm	000
ML-4	Ca	19-Sep-99	Residual Metals	5860	ppm	000
ML-4	Ca	25-Aug-99	Sediment Samples	21200	ppm	000
ML-4	Ca	25-Aug-99	Sediment Samples	11100	ppm	000
ML-4	Ca	25-Aug-99	Sediment Samples	7770	ppm	000
ML-4	Cd	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
ML-4	Cd	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
ML-4	Cd	19-Sep-99	Metals Bound to Iron and Manganese	1.4	ppm	000
ML-4	Cd	19-Sep-99	Metals Bound to Organic Matter	0.8	ppm	000
ML-4	Cd	19-Sep-99	Residual Metals	0.1	ppm	<=W
ML-4	Cd	25-Aug-99	Sediment Samples	0.9	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
ML-4	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
ML-4	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
ML-4	Cr	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
ML-4	Cr	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
ML-4	Cr	19-Sep-99	Metals Bound to Iron and Manganese	3.8	ppm	000
ML-4	Cr	19-Sep-99	Metals Bound to Organic Matter	11.3	ppm	000
ML-4	Cr	19-Sep-99	Residual Metals	28	ppm	000
ML-4	Cr	25-Aug-99	Sediment Samples	28	ppm	000
ML-4	Cr	25-Aug-99	Sediment Samples	21	ppm	000
ML-4	Cr	25-Aug-99	Sediment Samples	17	ppm	000
ML-4	Fe	19-Sep-99	Exchangeable Metals	6	ppm	000
ML-4	Fe	19-Sep-99	Metals Bound to Carbonates	986	ppm	000
ML-4	Fe	19-Sep-99	Metals Bound to Iron and Manganese	17400	ppm	000
ML-4	Fe	19-Sep-99	Metals Bound to Organic Matter	9570	ppm	000
ML-4	Fe	19-Sep-99	Residual Metals	23000	ppm	000
ML-4	Fe	25-Aug-99	Sediment Samples	43000	ppm	000
ML-4	Fe	25-Aug-99	Sediment Samples	66000	ppm	000
ML-4	Fe	25-Aug-99	Sediment Samples	65900	ppm	000
ML-4	K	19-Sep-99	Exchangeable Metals	302	ppm	000
ML-4	K	19-Sep-99	Metals Bound to Carbonates	80	ppm	<=W
ML-4	K	19-Sep-99	Metals Bound to Iron and Manganese	100	ppm	<=W
ML-4	K	19-Sep-99	Metals Bound to Organic Matter	100	ppm	<=W
ML-4	K	19-Sep-99	Residual Metals	10200	ppm	000
ML-4	K	25-Aug-99	Sediment Samples	1620	ppm	000
ML-4	K	25-Aug-99	Sediment Samples	1500	ppm	000
ML-4	K	25-Aug-99	Sediment Samples	677	ppm	000
ML-4	Mg	19-Sep-99	Exchangeable Metals	383	ppm	000
ML-4	Mg	19-Sep-99	Metals Bound to Carbonates	182	ppm	000
ML-4	Mg	19-Sep-99	Metals Bound to Iron and Manganese	1400	ppm	000
ML-4	Mg	19-Sep-99	Metals Bound to Organic Matter	964	ppm	000
ML-4	Mg	19-Sep-99	Residual Metals	7260	ppm	000
ML-4	Mg	25-Aug-99	Sediment Samples	5680	ppm	000
ML-4	Mg	25-Aug-99	Sediment Samples	5200	ppm	000
ML-4	Mg	25-Aug-99	Sediment Samples	3960	ppm	000
ML-4	Mn	19-Sep-99	Exchangeable Metals	158	ppm	000
ML-4	Mn	19-Sep-99	Metals Bound to Carbonates	326	ppm	000
ML-4	Mn	19-Sep-99	Metals Bound to Iron and Manganese	424	ppm	000
ML-4	Mn	19-Sep-99	Metals Bound to Organic Matter	78.2	ppm	000
ML-4	Mn	19-Sep-99	Residual Metals	185	ppm	000
ML-4	Mn	25-Aug-99	Sediment Samples	772	ppm	000
ML-4	Mn	25-Aug-99	Sediment Samples	905	ppm	000
ML-4	Mn	25-Aug-99	Sediment Samples	1070	ppm	000
ML-4	Mo	19-Sep-99	Exchangeable Metals	2	ppm	<=W
ML-4	Mo	19-Sep-99	Metals Bound to Carbonates	1	ppm	<=W
ML-4	Mo	19-Sep-99	Metals Bound to Iron and Manganese	2	ppm	<=W
ML-4	Mo	19-Sep-99	Metals Bound to Organic Matter	2	ppm	<=W
ML-4	Mo	19-Sep-99	Residual Metals	5	ppm	<=W

Station	Parameter	Date	Description	Result	Units	Remark
ML-4	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
ML-4	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
ML-4	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
ML-4	Na	19-Sep-99	Exchangeable Metals	0	ppm	ND
ML-4	Na	19-Sep-99	Metals Bound to Carbonates	0	ppm	ND
ML-4	Na	19-Sep-99	Metals Bound to Iron and Manganese	0	ppm	ND
ML-4	Na	19-Sep-99	Metals Bound to Organic Matter	0	ppm	ND
ML-4	Na	19-Sep-99	Residual Metals	0	ppm	ND
ML-4	Na	25-Aug-99	Sediment Samples	191	ppm	000
ML-4	Na	25-Aug-99	Sediment Samples	174	ppm	000
ML-4	Na	25-Aug-99	Sediment Samples	125	ppm	000
ML-4	P	19-Sep-99	Exchangeable Metals	19	ppm	000
ML-4	P	19-Sep-99	Metals Bound to Carbonates	45	ppm	000
ML-4	P	19-Sep-99	Metals Bound to Iron and Manganese	224	ppm	000
ML-4	P	19-Sep-99	Metals Bound to Organic Matter	149	ppm	000
ML-4	P	19-Sep-99	Residual Metals	1350	ppm	000
ML-4	P	25-Aug-99	Sediment Samples	1290	ppm	000
ML-4	P	25-Aug-99	Sediment Samples	1470	ppm	000
ML-4	P	25-Aug-99	Sediment Samples	1930	ppm	000
ML-4	S	19-Sep-99	Exchangeable Metals	799	ppm	000
ML-4	S	19-Sep-99	Metals Bound to Carbonates	168	ppm	000
ML-4	S	19-Sep-99	Metals Bound to Iron and Manganese	1120	ppm	000
ML-4	S	19-Sep-99	Metals Bound to Organic Matter	11900	ppm	000
ML-4	S	19-Sep-99	Residual Metals	0	ppm	ND
ML-4	S	25-Aug-99	Sediment Samples	0	ppm	ND
ML-4	S	25-Aug-99	Sediment Samples	0	ppm	ND
ML-4	S	25-Aug-99	Sediment Samples	0	ppm	ND
ML-4	Sb	19-Sep-99	Exchangeable Metals	8	ppm	<=W
ML-4	Sb	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
ML-4	Sb	19-Sep-99	Metals Bound to Iron and Manganese	107	ppm	000
ML-4	Sb	19-Sep-99	Metals Bound to Organic Matter	63	ppm	000
ML-4	Sb	19-Sep-99	Residual Metals	0	ppm	ND
ML-4	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
ML-4	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
ML-4	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
ML-4	Se	19-Sep-99	Exchangeable Metals	8	ppm	<=W
ML-4	Se	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
ML-4	Se	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
ML-4	Se	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
ML-4	Se	19-Sep-99	Residual Metals	0	ppm	ND
ML-4	Se	25-Aug-99	Sediment Samples	0	ppm	ND
ML-4	Se	25-Aug-99	Sediment Samples	0	ppm	ND
ML-4	Se	25-Aug-99	Sediment Samples	0	ppm	ND
ML-4	Sr	19-Sep-99	Exchangeable Metals	48.4	ppm	000
ML-4	Sr	19-Sep-99	Metals Bound to Carbonates	49.1	ppm	000
ML-4	Sr	19-Sep-99	Metals Bound to Iron and Manganese	30	ppm	000
ML-4	Sr	19-Sep-99	Metals Bound to Organic Matter	5.3	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
ML-4	Sr	19-Sep-99	Residual Metals	88	ppm	000
ML-4	Sr	25-Aug-99	Sediment Samples	113	ppm	000
ML-4	Sr	25-Aug-99	Sediment Samples	64.6	ppm	000
ML-4	Sr	25-Aug-99	Sediment Samples	41.7	ppm	000
ML-4	Ti	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
ML-4	Ti	19-Sep-99	Metals Bound to Carbonates	0.6	ppm	000
ML-4	Ti	19-Sep-99	Metals Bound to Iron and Manganese	0.6	ppm	000
ML-4	Ti	19-Sep-99	Metals Bound to Organic Matter	4.5	ppm	000
ML-4	Ti	19-Sep-99	Residual Metals	2060	ppm	000
ML-4	Ti	25-Aug-99	Sediment Samples	339	ppm	000
ML-4	Ti	25-Aug-99	Sediment Samples	363	ppm	000
ML-4	Ti	25-Aug-99	Sediment Samples	314	ppm	000
ML-4	V	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
ML-4	V	19-Sep-99	Metals Bound to Carbonates	1.8	ppm	000
ML-4	V	19-Sep-99	Metals Bound to Iron and Manganese	9.8	ppm	000
ML-4	V	19-Sep-99	Metals Bound to Organic Matter	11.7	ppm	000
ML-4	V	19-Sep-99	Residual Metals	41	ppm	000
ML-4	V	25-Aug-99	Sediment Samples	35	ppm	000
ML-4	V	25-Aug-99	Sediment Samples	42	ppm	000
ML-4	V	25-Aug-99	Sediment Samples	44	ppm	000
ML-4	Zn	19-Sep-99	Exchangeable Metals	0.5	ppm	000
ML-4	Zn	19-Sep-99	Metals Bound to Carbonates	24.6	ppm	000
ML-4	Zn	19-Sep-99	Metals Bound to Iron and Manganese	160	ppm	000
ML-4	Zn	19-Sep-99	Metals Bound to Organic Matter	59.4	ppm	000
ML-4	Zn	19-Sep-99	Residual Metals	47	ppm	000
ML-4	Zn	25-Aug-99	Sediment Samples	267	ppm	000
ML-4	Zn	25-Aug-99	Sediment Samples	178	ppm	000
ML-4	Zn	25-Aug-99	Sediment Samples	113	ppm	000
SL-2	As	19-Sep-99	Exchangeable Metals	0.2	ppm	<=W
SL-2	As	19-Sep-99	Metals Bound to Carbonates	6.1	ppm	000
SL-2	As	19-Sep-99	Metals Bound to Iron and Manganese	35	ppm	000
SL-2	As	19-Sep-99	Metals Bound to Organic Matter	1.1	ppm	000
SL-2	As	19-Sep-99	Residual Metals	42.9	ppm	000
SL-2	As	25-Aug-99	Sediment Samples	68.5	ppm	000
SL-2	As	25-Aug-99	Sediment Samples	58.8	ppm	000
SL-2	As	25-Aug-99	Sediment Samples	51.9	ppm	000
SL-2	Co	19-Sep-99	Exchangeable Metals	2	ppm	000
SL-2	Co	19-Sep-99	Metals Bound to Carbonates	24.8	ppm	000
SL-2	Co	19-Sep-99	Metals Bound to Iron and Manganese	114	ppm	000
SL-2	Co	19-Sep-99	Metals Bound to Organic Matter	31.7	ppm	000
SL-2	Co	19-Sep-99	Residual Metals	23	ppm	000
SL-2	Co	25-Aug-99	Sediment Samples	226	ppm	000
SL-2	Co	25-Aug-99	Sediment Samples	160	ppm	000
SL-2	Co	25-Aug-99	Sediment Samples	41	ppm	000
SL-2	Cu	19-Sep-99	Exchangeable Metals	0.3	ppm	<=W
SL-2	Cu	19-Sep-99	Metals Bound to Carbonates	0.3	ppm	<=W
SL-2	Cu	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W

Station	Parameter	Date	Description	Result	Units	Remark
SL-2	Cu	19-Sep-99	Metals Bound to Organic Matter	25.9	ppm	000
SL-2	Cu	19-Sep-99	Residual Metals	17.1	ppm	000
SL-2	Cu	25-Aug-99	Sediment Samples	43	ppm	000
SL-2	Cu	25-Aug-99	Sediment Samples	36	ppm	000
SL-2	Cu	25-Aug-99	Sediment Samples	23	ppm	000
SL-2	Ni	19-Sep-99	Exchangeable Metals	2	ppm	<=W
SL-2	Ni	19-Sep-99	Metals Bound to Carbonates	10	ppm	000
SL-2	Ni	19-Sep-99	Metals Bound to Iron and Manganese	58	ppm	000
SL-2	Ni	19-Sep-99	Metals Bound to Organic Matter	31	ppm	000
SL-2	Ni	19-Sep-99	Residual Metals	32	ppm	000
SL-2	Ni	25-Aug-99	Sediment Samples	164	ppm	000
SL-2	Ni	25-Aug-99	Sediment Samples	144	ppm	000
SL-2	Ni	25-Aug-99	Sediment Samples	46	ppm	000
SL-2	Pb	19-Sep-99	Exchangeable Metals	4	ppm	<=W
SL-2	Pb	19-Sep-99	Metals Bound to Carbonates	14	ppm	000
SL-2	Pb	19-Sep-99	Metals Bound to Iron and Manganese	24	ppm	000
SL-2	Pb	19-Sep-99	Metals Bound to Organic Matter	11	ppm	000
SL-2	Pb	19-Sep-99	Residual Metals	33	ppm	000
SL-2	Pb	25-Aug-99	Sediment Samples	73	ppm	000
SL-2	Pb	25-Aug-99	Sediment Samples	44	ppm	000
SL-2	Pb	25-Aug-99	Sediment Samples	14	ppm	000
SL-2	Hg	19-Sep-99	Exchangeable Metals	0.01	ppm	<=W
SL-2	Hg	19-Sep-99	Metals Bound to Carbonates	0.01	ppm	<=W
SL-2	Hg	19-Sep-99	Metals Bound to Iron and Manganese	0.02	ppm	<=W
SL-2	Hg	19-Sep-99	Metals Bound to Organic Matter	0.02	ppm	<=W
SL-2	Hg	19-Sep-99	Residual Metals	0.32	ppm	000
SL-2	Hg	25-Aug-99	Sediment Samples	0.27	ppm	000
SL-2	Hg	25-Aug-99	Sediment Samples	0.25	ppm	000
SL-2	Hg	25-Aug-99	Sediment Samples	0.14	ppm	000
SL-2	U	19-Sep-99	Exchangeable Metals	0.3	ppm	000
SL-2	U	19-Sep-99	Metals Bound to Carbonates	1.3	ppm	000
SL-2	U	19-Sep-99	Metals Bound to Iron and Manganese	1.2	ppm	000
SL-2	U	19-Sep-99	Metals Bound to Organic Matter	0.4	ppm	000
SL-2	U	19-Sep-99	Residual Metals	0.8	ppm	000
SL-2	U	25-Aug-99	Sediment Samples	2.85	ppm	000
SL-2	U	25-Aug-99	Sediment Samples	3.34	ppm	000
SL-2	U	25-Aug-99	Sediment Samples	3.47	ppm	000
SL-2	Ag	19-Sep-99	Exchangeable Metals	0.3	ppm	<=W
SL-2	Ag	19-Sep-99	Metals Bound to Carbonates	0.3	ppm	<=W
SL-2	Ag	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
SL-2	Ag	19-Sep-99	Metals Bound to Organic Matter	0.3	ppm	000
SL-2	Ag	19-Sep-99	Residual Metals	0.1	ppm	<=W
SL-2	Ag	25-Aug-99	Sediment Samples	0.8	ppm	<=W
SL-2	Ag	25-Aug-99	Sediment Samples	0.8	ppm	<=W
SL-2	Ag	25-Aug-99	Sediment Samples	0.8	ppm	<=W
SL-2	Al	19-Sep-99	Exchangeable Metals	3	ppm	<=W
SL-2	Al	19-Sep-99	Metals Bound to Carbonates	120	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
SL-2	Al	19-Sep-99	Metals Bound to Iron and Manganese	1310	ppm	000
SL-2	Al	19-Sep-99	Metals Bound to Organic Matter	3110	ppm	000
SL-2	Al	19-Sep-99	Residual Metals	42100	ppm	000
SL-2	Al	25-Aug-99	Sediment Samples	18400	ppm	000
SL-2	Al	25-Aug-99	Sediment Samples	17500	ppm	000
SL-2	Al	25-Aug-99	Sediment Samples	17600	ppm	000
SL-2	Ba	19-Sep-99	Exchangeable Metals	62.5	ppm	000
SL-2	Ba	19-Sep-99	Metals Bound to Carbonates	69	ppm	000
SL-2	Ba	19-Sep-99	Metals Bound to Iron and Manganese	93.9	ppm	000
SL-2	Ba	19-Sep-99	Metals Bound to Organic Matter	31.6	ppm	000
SL-2	Ba	19-Sep-99	Residual Metals	379	ppm	000
SL-2	Ba	25-Aug-99	Sediment Samples	330	ppm	000
SL-2	Ba	25-Aug-99	Sediment Samples	297	ppm	000
SL-2	Ba	25-Aug-99	Sediment Samples	291	ppm	000
SL-2	Be	19-Sep-99	Exchangeable Metals	0.04	ppm	<=W
SL-2	Be	19-Sep-99	Metals Bound to Carbonates	0.04	ppm	000
SL-2	Be	19-Sep-99	Metals Bound to Iron and Manganese	0.29	ppm	000
SL-2	Be	19-Sep-99	Metals Bound to Organic Matter	0.06	ppm	000
SL-2	Be	19-Sep-99	Residual Metals	0.96	ppm	000
SL-2	Be	25-Aug-99	Sediment Samples	0.8	ppm	000
SL-2	Be	25-Aug-99	Sediment Samples	0.8	ppm	000
SL-2	Be	25-Aug-99	Sediment Samples	0.7	ppm	000
SL-2	Bi	19-Sep-99	Exchangeable Metals	8	ppm	<=W
SL-2	Bi	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
SL-2	Bi	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
SL-2	Bi	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
SL-2	Bi	19-Sep-99	Residual Metals	0	ppm	ND
SL-2	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
SL-2	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
SL-2	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
SL-2	Ca	19-Sep-99	Exchangeable Metals	3600	ppm	000
SL-2	Ca	19-Sep-99	Metals Bound to Carbonates	1960	ppm	000
SL-2	Ca	19-Sep-99	Metals Bound to Iron and Manganese	1670	ppm	000
SL-2	Ca	19-Sep-99	Metals Bound to Organic Matter	243	ppm	000
SL-2	Ca	19-Sep-99	Residual Metals	11100	ppm	000
SL-2	Ca	25-Aug-99	Sediment Samples	8100	ppm	000
SL-2	Ca	25-Aug-99	Sediment Samples	7890	ppm	000
SL-2	Ca	25-Aug-99	Sediment Samples	8880	ppm	000
SL-2	Cd	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
SL-2	Cd	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
SL-2	Cd	19-Sep-99	Metals Bound to Iron and Manganese	2	ppm	000
SL-2	Cd	19-Sep-99	Metals Bound to Organic Matter	0.5	ppm	<=W
SL-2	Cd	19-Sep-99	Residual Metals	0.1	ppm	<=W
SL-2	Cd	25-Aug-99	Sediment Samples	1.7	ppm	000
SL-2	Cd	25-Aug-99	Sediment Samples	0.9	ppm	000
SL-2	Cd	25-Aug-99	Sediment Samples	0.5	ppm	000
SL-2	Cr	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W

Station	Parameter	Date	Description	Result	Units	Remark
SL-2	Cr	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
SL-2	Cr	19-Sep-99	Metals Bound to Iron and Manganese	6.5	ppm	000
SL-2	Cr	19-Sep-99	Metals Bound to Organic Matter	8.4	ppm	000
SL-2	Cr	19-Sep-99	Residual Metals	50	ppm	000
SL-2	Cr	25-Aug-99	Sediment Samples	42	ppm	000
SL-2	Cr	25-Aug-99	Sediment Samples	40	ppm	000
SL-2	Cr	25-Aug-99	Sediment Samples	39	ppm	000
SL-2	Fe	19-Sep-99	Exchangeable Metals	3	ppm	000
SL-2	Fe	19-Sep-99	Metals Bound to Carbonates	3020	ppm	000
SL-2	Fe	19-Sep-99	Metals Bound to Iron and Manganese	17400	ppm	000
SL-2	Fe	19-Sep-99	Metals Bound to Organic Matter	4430	ppm	000
SL-2	Fe	19-Sep-99	Residual Metals	30500	ppm	000
SL-2	Fe	25-Aug-99	Sediment Samples	44300	ppm	000
SL-2	Fe	25-Aug-99	Sediment Samples	37300	ppm	000
SL-2	Fe	25-Aug-99	Sediment Samples	34700	ppm	000
SL-2	K	19-Sep-99	Exchangeable Metals	176	ppm	000
SL-2	K	19-Sep-99	Metals Bound to Carbonates	80	ppm	<=W
SL-2	K	19-Sep-99	Metals Bound to Iron and Manganese	100	ppm	<=W
SL-2	K	19-Sep-99	Metals Bound to Organic Matter	100	ppm	<=W
SL-2	K	19-Sep-99	Residual Metals	10200	ppm	000
SL-2	K	25-Aug-99	Sediment Samples	1360	ppm	000
SL-2	K	25-Aug-99	Sediment Samples	1560	ppm	000
SL-2	K	25-Aug-99	Sediment Samples	1540	ppm	000
SL-2	Mg	19-Sep-99	Exchangeable Metals	221	ppm	000
SL-2	Mg	19-Sep-99	Metals Bound to Carbonates	77	ppm	000
SL-2	Mg	19-Sep-99	Metals Bound to Iron and Manganese	526	ppm	000
SL-2	Mg	19-Sep-99	Metals Bound to Organic Matter	553	ppm	000
SL-2	Mg	19-Sep-99	Residual Metals	9490	ppm	000
SL-2	Mg	25-Aug-99	Sediment Samples	6990	ppm	000
SL-2	Mg	25-Aug-99	Sediment Samples	6790	ppm	000
SL-2	Mg	25-Aug-99	Sediment Samples	6670	ppm	000
SL-2	Mn	19-Sep-99	Exchangeable Metals	405	ppm	000
SL-2	Mn	19-Sep-99	Metals Bound to Carbonates	447	ppm	000
SL-2	Mn	19-Sep-99	Metals Bound to Iron and Manganese	562	ppm	000
SL-2	Mn	19-Sep-99	Metals Bound to Organic Matter	80.6	ppm	000
SL-2	Mn	19-Sep-99	Residual Metals	331	ppm	000
SL-2	Mn	25-Aug-99	Sediment Samples	1540	ppm	000
SL-2	Mn	25-Aug-99	Sediment Samples	1300	ppm	000
SL-2	Mn	25-Aug-99	Sediment Samples	1300	ppm	000
SL-2	Mo	19-Sep-99	Exchangeable Metals	2	ppm	<=W
SL-2	Mo	19-Sep-99	Metals Bound to Carbonates	1	ppm	<=W
SL-2	Mo	19-Sep-99	Metals Bound to Iron and Manganese	2	ppm	<=W
SL-2	Mo	19-Sep-99	Metals Bound to Organic Matter	2	ppm	<=W
SL-2	Mo	19-Sep-99	Residual Metals	5	ppm	<=W
SL-2	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
SL-2	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
SL-2	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W

Station	Parameter	Date	Description	Result	Units	Remark
SL-2	Na	19-Sep-99	Exchangeable Metals	0	ppm	ND
SL-2	Na	19-Sep-99	Metals Bound to Carbonates	0	ppm	ND
SL-2	Na	19-Sep-99	Metals Bound to Iron and Manganese	0	ppm	ND
SL-2	Na	19-Sep-99	Metals Bound to Organic Matter	0	ppm	ND
SL-2	Na	19-Sep-99	Residual Metals	0	ppm	ND
SL-2	Na	25-Aug-99	Sediment Samples	260	ppm	000
SL-2	Na	25-Aug-99	Sediment Samples	265	ppm	000
SL-2	Na	25-Aug-99	Sediment Samples	288	ppm	000
SL-2	P	19-Sep-99	Exchangeable Metals	8	ppm	<=W
SL-2	P	19-Sep-99	Metals Bound to Carbonates	46	ppm	000
SL-2	P	19-Sep-99	Metals Bound to Iron and Manganese	132	ppm	000
SL-2	P	19-Sep-99	Metals Bound to Organic Matter	86	ppm	000
SL-2	P	19-Sep-99	Residual Metals	1260	ppm	000
SL-2	P	25-Aug-99	Sediment Samples	1310	ppm	000
SL-2	P	25-Aug-99	Sediment Samples	1150	ppm	000
SL-2	P	25-Aug-99	Sediment Samples	1150	ppm	000
SL-2	S	19-Sep-99	Exchangeable Metals	75	ppm	000
SL-2	S	19-Sep-99	Metals Bound to Carbonates	39	ppm	000
SL-2	S	19-Sep-99	Metals Bound to Iron and Manganese	347	ppm	000
SL-2	S	19-Sep-99	Metals Bound to Organic Matter	2260	ppm	000
SL-2	S	19-Sep-99	Residual Metals	0	ppm	ND
SL-2	S	25-Aug-99	Sediment Samples	0	ppm	ND
SL-2	S	25-Aug-99	Sediment Samples	0	ppm	ND
SL-2	S	25-Aug-99	Sediment Samples	0	ppm	ND
SL-2	Sb	19-Sep-99	Exchangeable Metals	8	ppm	<=W
SL-2	Sb	19-Sep-99	Metals Bound to Carbonates	17	ppm	000
SL-2	Sb	19-Sep-99	Metals Bound to Iron and Manganese	116	ppm	000
SL-2	Sb	19-Sep-99	Metals Bound to Organic Matter	20	ppm	000
SL-2	Sb	19-Sep-99	Residual Metals	0	ppm	ND
SL-2	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
SL-2	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
SL-2	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
SL-2	Se	19-Sep-99	Exchangeable Metals	8	ppm	<=W
SL-2	Se	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
SL-2	Se	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
SL-2	Se	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
SL-2	Se	19-Sep-99	Residual Metals	0	ppm	ND
SL-2	Se	25-Aug-99	Sediment Samples	0	ppm	ND
SL-2	Se	25-Aug-99	Sediment Samples	0	ppm	ND
SL-2	Se	25-Aug-99	Sediment Samples	0	ppm	ND
SL-2	Sr	19-Sep-99	Exchangeable Metals	34.2	ppm	000
SL-2	Sr	19-Sep-99	Metals Bound to Carbonates	16.6	ppm	000
SL-2	Sr	19-Sep-99	Metals Bound to Iron and Manganese	12.5	ppm	000
SL-2	Sr	19-Sep-99	Metals Bound to Organic Matter	2.2	ppm	000
SL-2	Sr	19-Sep-99	Residual Metals	159	ppm	000
SL-2	Sr	25-Aug-99	Sediment Samples	71.5	ppm	000
SL-2	Sr	25-Aug-99	Sediment Samples	70.1	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
SL-2	Sr	25-Aug-99	Sediment Samples	80.4	ppm	000
SL-2	Ti	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
SL-2	Ti	19-Sep-99	Metals Bound to Carbonates	1.2	ppm	000
SL-2	Ti	19-Sep-99	Metals Bound to Iron and Manganese	0.7	ppm	000
SL-2	Ti	19-Sep-99	Metals Bound to Organic Matter	2.5	ppm	000
SL-2	Ti	19-Sep-99	Residual Metals	2930	ppm	000
SL-2	Ti	25-Aug-99	Sediment Samples	615	ppm	000
SL-2	Ti	25-Aug-99	Sediment Samples	626	ppm	000
SL-2	Ti	25-Aug-99	Sediment Samples	663	ppm	000
SL-2	V	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
SL-2	V	19-Sep-99	Metals Bound to Carbonates	4	ppm	000
SL-2	V	19-Sep-99	Metals Bound to Iron and Manganese	12.9	ppm	000
SL-2	V	19-Sep-99	Metals Bound to Organic Matter	5.4	ppm	000
SL-2	V	19-Sep-99	Residual Metals	64	ppm	000
SL-2	V	25-Aug-99	Sediment Samples	51	ppm	000
SL-2	V	25-Aug-99	Sediment Samples	50	ppm	000
SL-2	V	25-Aug-99	Sediment Samples	47	ppm	000
SL-2	Zn	19-Sep-99	Exchangeable Metals	1.7	ppm	000
SL-2	Zn	19-Sep-99	Metals Bound to Carbonates	50.4	ppm	000
SL-2	Zn	19-Sep-99	Metals Bound to Iron and Manganese	299	ppm	000
SL-2	Zn	19-Sep-99	Metals Bound to Organic Matter	65.7	ppm	000
SL-2	Zn	19-Sep-99	Residual Metals	135	ppm	000
SL-2	Zn	25-Aug-99	Sediment Samples	588	ppm	000
SL-2	Zn	25-Aug-99	Sediment Samples	411	ppm	000
SL-2	Zn	25-Aug-99	Sediment Samples	192	ppm	000
SL-4	As	19-Sep-99	Exchangeable Metals	0.5	ppm	000
SL-4	As	19-Sep-99	Metals Bound to Carbonates	6.7	ppm	000
SL-4	As	19-Sep-99	Metals Bound to Iron and Manganese	63.7	ppm	000
SL-4	As	19-Sep-99	Metals Bound to Organic Matter	2.7	ppm	000
SL-4	As	19-Sep-99	Residual Metals	78.1	ppm	000
SL-4	As	25-Aug-99	Sediment Samples	100	ppm	000
SL-4	As	25-Aug-99	Sediment Samples	100	ppm	000
SL-4	As	25-Aug-99	Sediment Samples	95.6	ppm	000
SL-4	Co	19-Sep-99	Exchangeable Metals	4.4	ppm	000
SL-4	Co	19-Sep-99	Metals Bound to Carbonates	16.9	ppm	000
SL-4	Co	19-Sep-99	Metals Bound to Iron and Manganese	102	ppm	000
SL-4	Co	19-Sep-99	Metals Bound to Organic Matter	32.4	ppm	000
SL-4	Co	19-Sep-99	Residual Metals	26	ppm	000
SL-4	Co	25-Aug-99	Sediment Samples	170	ppm	000
SL-4	Co	25-Aug-99	Sediment Samples	269	ppm	000
SL-4	Co	25-Aug-99	Sediment Samples	230	ppm	000
SL-4	Cu	19-Sep-99	Exchangeable Metals	0.7	ppm	000
SL-4	Cu	19-Sep-99	Metals Bound to Carbonates	0.6	ppm	000
SL-4	Cu	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
SL-4	Cu	19-Sep-99	Metals Bound to Organic Matter	34.3	ppm	000
SL-4	Cu	19-Sep-99	Residual Metals	17.6	ppm	000
SL-4	Cu	25-Aug-99	Sediment Samples	46	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
SL-4	Cu	25-Aug-99	Sediment Samples	61	ppm	000
SL-4	Cu	25-Aug-99	Sediment Samples	52	ppm	000
SL-4	Ni	19-Sep-99	Exchangeable Metals	2	ppm	<=W
SL-4	Ni	19-Sep-99	Metals Bound to Carbonates	7	ppm	000
SL-4	Ni	19-Sep-99	Metals Bound to Iron and Manganese	46	ppm	000
SL-4	Ni	19-Sep-99	Metals Bound to Organic Matter	31	ppm	000
SL-4	Ni	19-Sep-99	Residual Metals	32	ppm	000
SL-4	Ni	25-Aug-99	Sediment Samples	109	ppm	000
SL-4	Ni	25-Aug-99	Sediment Samples	183	ppm	000
SL-4	Ni	25-Aug-99	Sediment Samples	201	ppm	000
SL-4	Pb	19-Sep-99	Exchangeable Metals	4	ppm	<=W
SL-4	Pb	19-Sep-99	Metals Bound to Carbonates	10	ppm	000
SL-4	Pb	19-Sep-99	Metals Bound to Iron and Manganese	20	ppm	000
SL-4	Pb	19-Sep-99	Metals Bound to Organic Matter	9	ppm	000
SL-4	Pb	19-Sep-99	Residual Metals	47	ppm	000
SL-4	Pb	25-Aug-99	Sediment Samples	87	ppm	000
SL-4	Pb	25-Aug-99	Sediment Samples	103	ppm	000
SL-4	Pb	25-Aug-99	Sediment Samples	79	ppm	000
SL-4	Hg	19-Sep-99	Exchangeable Metals	0.01	ppm	<=W
SL-4	Hg	19-Sep-99	Metals Bound to Carbonates	0.01	ppm	<=W
SL-4	Hg	19-Sep-99	Metals Bound to Iron and Manganese	0.02	ppm	000
SL-4	Hg	19-Sep-99	Metals Bound to Organic Matter	0.02	ppm	<=W
SL-4	Hg	19-Sep-99	Residual Metals	0.3	ppm	000
SL-4	Hg	25-Aug-99	Sediment Samples	0.29	ppm	000
SL-4	Hg	25-Aug-99	Sediment Samples	0.26	ppm	000
SL-4	Hg	25-Aug-99	Sediment Samples	0.23	ppm	000
SL-4	U	19-Sep-99	Exchangeable Metals	0.3	ppm	000
SL-4	U	19-Sep-99	Metals Bound to Carbonates	1.2	ppm	000
SL-4	U	19-Sep-99	Metals Bound to Iron and Manganese	1.1	ppm	000
SL-4	U	19-Sep-99	Metals Bound to Organic Matter	0.3	ppm	000
SL-4	U	19-Sep-99	Residual Metals	0.9	ppm	000
SL-4	U	25-Aug-99	Sediment Samples	3.27	ppm	000
SL-4	U	25-Aug-99	Sediment Samples	3.98	ppm	000
SL-4	U	25-Aug-99	Sediment Samples	4.6	ppm	000
SL-4	Ag	19-Sep-99	Exchangeable Metals	0.3	ppm	<=W
SL-4	Ag	19-Sep-99	Metals Bound to Carbonates	0.3	ppm	<=W
SL-4	Ag	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
SL-4	Ag	19-Sep-99	Metals Bound to Organic Matter	0.5	ppm	000
SL-4	Ag	19-Sep-99	Residual Metals	0.1	ppm	<=W
SL-4	Ag	25-Aug-99	Sediment Samples	0.8	ppm	<=W
SL-4	Ag	25-Aug-99	Sediment Samples	0.8	ppm	<=W
SL-4	Ag	25-Aug-99	Sediment Samples	0.8	ppm	<=W
SL-4	Al	19-Sep-99	Exchangeable Metals	3	ppm	<=W
SL-4	Al	19-Sep-99	Metals Bound to Carbonates	73	ppm	000
SL-4	Al	19-Sep-99	Metals Bound to Iron and Manganese	1080	ppm	000
SL-4	Al	19-Sep-99	Metals Bound to Organic Matter	3690	ppm	000
SL-4	Al	19-Sep-99	Residual Metals	35800	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
SL-4	Al	25-Aug-99	Sediment Samples	18800	ppm	000
SL-4	Al	25-Aug-99	Sediment Samples	22800	ppm	000
SL-4	Al	25-Aug-99	Sediment Samples	23100	ppm	000
SL-4	Ba	19-Sep-99	Exchangeable Metals	73.6	ppm	000
SL-4	Ba	19-Sep-99	Metals Bound to Carbonates	85.6	ppm	000
SL-4	Ba	19-Sep-99	Metals Bound to Iron and Manganese	133	ppm	000
SL-4	Ba	19-Sep-99	Metals Bound to Organic Matter	28.5	ppm	000
SL-4	Ba	19-Sep-99	Residual Metals	382	ppm	000
SL-4	Ba	25-Aug-99	Sediment Samples	332	ppm	000
SL-4	Ba	25-Aug-99	Sediment Samples	384	ppm	000
SL-4	Ba	25-Aug-99	Sediment Samples	351	ppm	000
SL-4	Be	19-Sep-99	Exchangeable Metals	0.04	ppm	<=W
SL-4	Be	19-Sep-99	Metals Bound to Carbonates	0.05	ppm	000
SL-4	Be	19-Sep-99	Metals Bound to Iron and Manganese	0.29	ppm	000
SL-4	Be	19-Sep-99	Metals Bound to Organic Matter	0.08	ppm	000
SL-4	Be	19-Sep-99	Residual Metals	0.93	ppm	000
SL-4	Be	25-Aug-99	Sediment Samples	0.9	ppm	000
SL-4	Be	25-Aug-99	Sediment Samples	1	ppm	000
SL-4	Be	25-Aug-99	Sediment Samples	1	ppm	000
SL-4	Bi	19-Sep-99	Exchangeable Metals	8	ppm	<=W
SL-4	Bi	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
SL-4	Bi	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
SL-4	Bi	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
SL-4	Bi	19-Sep-99	Residual Metals	0	ppm	ND
SL-4	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
SL-4	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
SL-4	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
SL-4	Ca	19-Sep-99	Exchangeable Metals	4130	ppm	000
SL-4	Ca	19-Sep-99	Metals Bound to Carbonates	1700	ppm	000
SL-4	Ca	19-Sep-99	Metals Bound to Iron and Manganese	1630	ppm	000
SL-4	Ca	19-Sep-99	Metals Bound to Organic Matter	313	ppm	000
SL-4	Ca	19-Sep-99	Residual Metals	8320	ppm	000
SL-4	Ca	25-Aug-99	Sediment Samples	8990	ppm	000
SL-4	Ca	25-Aug-99	Sediment Samples	9730	ppm	000
SL-4	Ca	25-Aug-99	Sediment Samples	9790	ppm	000
SL-4	Cd	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
SL-4	Cd	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	000
SL-4	Cd	19-Sep-99	Metals Bound to Iron and Manganese	1.9	ppm	000
SL-4	Cd	19-Sep-99	Metals Bound to Organic Matter	0.5	ppm	000
SL-4	Cd	19-Sep-99	Residual Metals	0.1	ppm	<=W
SL-4	Cd	25-Aug-99	Sediment Samples	1.5	ppm	000
SL-4	Cd	25-Aug-99	Sediment Samples	2.7	ppm	000
SL-4	Cd	25-Aug-99	Sediment Samples	2.5	ppm	000
SL-4	Cr	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
SL-4	Cr	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
SL-4	Cr	19-Sep-99	Metals Bound to Iron and Manganese	6	ppm	000
SL-4	Cr	19-Sep-99	Metals Bound to Organic Matter	8.6	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
SL-4	Cr	19-Sep-99	Residual Metals	49	ppm	000
SL-4	Cr	25-Aug-99	Sediment Samples	41	ppm	000
SL-4	Cr	25-Aug-99	Sediment Samples	49	ppm	000
SL-4	Cr	25-Aug-99	Sediment Samples	49	ppm	000
SL-4	Fe	19-Sep-99	Exchangeable Metals	17	ppm	000
SL-4	Fe	19-Sep-99	Metals Bound to Carbonates	2250	ppm	000
SL-4	Fe	19-Sep-99	Metals Bound to Iron and Manganese	24900	ppm	000
SL-4	Fe	19-Sep-99	Metals Bound to Organic Matter	6820	ppm	000
SL-4	Fe	19-Sep-99	Residual Metals	32500	ppm	000
SL-4	Fe	25-Aug-99	Sediment Samples	51700	ppm	000
SL-4	Fe	25-Aug-99	Sediment Samples	54100	ppm	000
SL-4	Fe	25-Aug-99	Sediment Samples	51900	ppm	000
SL-4	K	19-Sep-99	Exchangeable Metals	265	ppm	000
SL-4	K	19-Sep-99	Metals Bound to Carbonates	80	ppm	<=W
SL-4	K	19-Sep-99	Metals Bound to Iron and Manganese	100	ppm	<=W
SL-4	K	19-Sep-99	Metals Bound to Organic Matter	100	ppm	<=W
SL-4	K	19-Sep-99	Residual Metals	10000	ppm	000
SL-4	K	25-Aug-99	Sediment Samples	1670	ppm	000
SL-4	K	25-Aug-99	Sediment Samples	2090	ppm	000
SL-4	K	25-Aug-99	Sediment Samples	1990	ppm	000
SL-4	Mg	19-Sep-99	Exchangeable Metals	261	ppm	000
SL-4	Mg	19-Sep-99	Metals Bound to Carbonates	74	ppm	000
SL-4	Mg	19-Sep-99	Metals Bound to Iron and Manganese	446	ppm	000
SL-4	Mg	19-Sep-99	Metals Bound to Organic Matter	593	ppm	000
SL-4	Mg	19-Sep-99	Residual Metals	8580	ppm	000
SL-4	Mg	25-Aug-99	Sediment Samples	6710	ppm	000
SL-4	Mg	25-Aug-99	Sediment Samples	7690	ppm	000
SL-4	Mg	25-Aug-99	Sediment Samples	7800	ppm	000
SL-4	Mn	19-Sep-99	Exchangeable Metals	694	ppm	000
SL-4	Mn	19-Sep-99	Metals Bound to Carbonates	522	ppm	000
SL-4	Mn	19-Sep-99	Metals Bound to Iron and Manganese	837	ppm	000
SL-4	Mn	19-Sep-99	Metals Bound to Organic Matter	140	ppm	000
SL-4	Mn	19-Sep-99	Residual Metals	272	ppm	000
SL-4	Mn	25-Aug-99	Sediment Samples	1650	ppm	000
SL-4	Mn	25-Aug-99	Sediment Samples	1420	ppm	000
SL-4	Mn	25-Aug-99	Sediment Samples	1270	ppm	000
SL-4	Mo	19-Sep-99	Exchangeable Metals	2	ppm	<=W
SL-4	Mo	19-Sep-99	Metals Bound to Carbonates	1	ppm	<=W
SL-4	Mo	19-Sep-99	Metals Bound to Iron and Manganese	2	ppm	<=W
SL-4	Mo	19-Sep-99	Metals Bound to Organic Matter	2	ppm	<=W
SL-4	Mo	19-Sep-99	Residual Metals	5	ppm	<=W
SL-4	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
SL-4	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
SL-4	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
SL-4	Na	19-Sep-99	Exchangeable Metals	0	ppm	ND
SL-4	Na	19-Sep-99	Metals Bound to Carbonates	0	ppm	ND
SL-4	Na	19-Sep-99	Metals Bound to Iron and Manganese	0	ppm	ND

Station	Parameter	Date	Description	Result	Units	Remark
SL-4	Na	19-Sep-99	Metals Bound to Organic Matter	0	ppm	ND
SL-4	Na	19-Sep-99	Residual Metals	0	ppm	ND
SL-4	Na	25-Aug-99	Sediment Samples	263	ppm	000
SL-4	Na	25-Aug-99	Sediment Samples	297	ppm	000
SL-4	Na	25-Aug-99	Sediment Samples	276	ppm	000
SL-4	P	19-Sep-99	Exchangeable Metals	8	ppm	<=W
SL-4	P	19-Sep-99	Metals Bound to Carbonates	66	ppm	000
SL-4	P	19-Sep-99	Metals Bound to Iron and Manganese	284	ppm	000
SL-4	P	19-Sep-99	Metals Bound to Organic Matter	122	ppm	000
SL-4	P	19-Sep-99	Residual Metals	2210	ppm	000
SL-4	P	25-Aug-99	Sediment Samples	2110	ppm	000
SL-4	P	25-Aug-99	Sediment Samples	1680	ppm	000
SL-4	P	25-Aug-99	Sediment Samples	1470	ppm	000
SL-4	S	19-Sep-99	Exchangeable Metals	231	ppm	000
SL-4	S	19-Sep-99	Metals Bound to Carbonates	77	ppm	000
SL-4	S	19-Sep-99	Metals Bound to Iron and Manganese	516	ppm	000
SL-4	S	19-Sep-99	Metals Bound to Organic Matter	3140	ppm	000
SL-4	S	19-Sep-99	Residual Metals	0	ppm	ND
SL-4	S	25-Aug-99	Sediment Samples	0	ppm	ND
SL-4	S	25-Aug-99	Sediment Samples	0	ppm	ND
SL-4	S	25-Aug-99	Sediment Samples	0	ppm	ND
SL-4	Sb	19-Sep-99	Exchangeable Metals	8	ppm	<=W
SL-4	Sb	19-Sep-99	Metals Bound to Carbonates	14	ppm	000
SL-4	Sb	19-Sep-99	Metals Bound to Iron and Manganese	154	ppm	000
SL-4	Sb	19-Sep-99	Metals Bound to Organic Matter	38	ppm	000
SL-4	Sb	19-Sep-99	Residual Metals	0	ppm	ND
SL-4	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
SL-4	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
SL-4	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
SL-4	Se	19-Sep-99	Exchangeable Metals	8	ppm	<=W
SL-4	Se	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
SL-4	Se	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
SL-4	Se	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
SL-4	Se	19-Sep-99	Residual Metals	0	ppm	ND
SL-4	Se	25-Aug-99	Sediment Samples	0	ppm	ND
SL-4	Se	25-Aug-99	Sediment Samples	0	ppm	ND
SL-4	Se	25-Aug-99	Sediment Samples	0	ppm	ND
SL-4	Sr	19-Sep-99	Exchangeable Metals	42.8	ppm	000
SL-4	Sr	19-Sep-99	Metals Bound to Carbonates	20.5	ppm	000
SL-4	Sr	19-Sep-99	Metals Bound to Iron and Manganese	18.2	ppm	000
SL-4	Sr	19-Sep-99	Metals Bound to Organic Matter	3.6	ppm	000
SL-4	Sr	19-Sep-99	Residual Metals	119	ppm	000
SL-4	Sr	25-Aug-99	Sediment Samples	87.9	ppm	000
SL-4	Sr	25-Aug-99	Sediment Samples	95.9	ppm	000
SL-4	Sr	25-Aug-99	Sediment Samples	95.3	ppm	000
SL-4	Ti	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
SL-4	Ti	19-Sep-99	Metals Bound to Carbonates	0.8	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
SL-4	Ti	19-Sep-99	Metals Bound to Iron and Manganese	0.6	ppm	000
SL-4	Ti	19-Sep-99	Metals Bound to Organic Matter	1.5	ppm	000
SL-4	Ti	19-Sep-99	Residual Metals	2770	ppm	000
SL-4	Ti	25-Aug-99	Sediment Samples	606	ppm	000
SL-4	Ti	25-Aug-99	Sediment Samples	710	ppm	000
SL-4	Ti	25-Aug-99	Sediment Samples	725	ppm	000
SL-4	V	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
SL-4	V	19-Sep-99	Metals Bound to Carbonates	3.3	ppm	000
SL-4	V	19-Sep-99	Metals Bound to Iron and Manganese	18.1	ppm	000
SL-4	V	19-Sep-99	Metals Bound to Organic Matter	7.1	ppm	000
SL-4	V	19-Sep-99	Residual Metals	64	ppm	000
SL-4	V	25-Aug-99	Sediment Samples	56	ppm	000
SL-4	V	25-Aug-99	Sediment Samples	64	ppm	000
SL-4	V	25-Aug-99	Sediment Samples	64	ppm	000
SL-4	Zn	19-Sep-99	Exchangeable Metals	6.1	ppm	000
SL-4	Zn	19-Sep-99	Metals Bound to Carbonates	47.1	ppm	000
SL-4	Zn	19-Sep-99	Metals Bound to Iron and Manganese	273	ppm	000
SL-4	Zn	19-Sep-99	Metals Bound to Organic Matter	86.2	ppm	000
SL-4	Zn	19-Sep-99	Residual Metals	100	ppm	000
SL-4	Zn	25-Aug-99	Sediment Samples	534	ppm	000
SL-4	Zn	25-Aug-99	Sediment Samples	856	ppm	000
SL-4	Zn	25-Aug-99	Sediment Samples	791	ppm	000
SL-5	As	19-Sep-99	Exchangeable Metals	0.2	ppm	000
SL-5	As	19-Sep-99	Metals Bound to Carbonates	4.3	ppm	000
SL-5	As	19-Sep-99	Metals Bound to Iron and Manganese	28.5	ppm	000
SL-5	As	19-Sep-99	Metals Bound to Organic Matter	0.6	ppm	000
SL-5	As	19-Sep-99	Residual Metals	38.8	ppm	000
SL-5	As	25-Aug-99	Sediment Samples	95.6	ppm	000
SL-5	As	25-Aug-99	Sediment Samples	112	ppm	000
SL-5	As	25-Aug-99	Sediment Samples	81.2	ppm	000
SL-5	Co	19-Sep-99	Exchangeable Metals	2	ppm	000
SL-5	Co	19-Sep-99	Metals Bound to Carbonates	6.9	ppm	000
SL-5	Co	19-Sep-99	Metals Bound to Iron and Manganese	38.9	ppm	000
SL-5	Co	19-Sep-99	Metals Bound to Organic Matter	10.4	ppm	000
SL-5	Co	19-Sep-99	Residual Metals	18	ppm	000
SL-5	Co	25-Aug-99	Sediment Samples	101	ppm	000
SL-5	Co	25-Aug-99	Sediment Samples	133	ppm	000
SL-5	Co	25-Aug-99	Sediment Samples	74	ppm	000
SL-5	Cu	19-Sep-99	Exchangeable Metals	0.9	ppm	000
SL-5	Cu	19-Sep-99	Metals Bound to Carbonates	0.8	ppm	000
SL-5	Cu	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
SL-5	Cu	19-Sep-99	Metals Bound to Organic Matter	27.4	ppm	000
SL-5	Cu	19-Sep-99	Residual Metals	17.7	ppm	000
SL-5	Cu	25-Aug-99	Sediment Samples	69	ppm	000
SL-5	Cu	25-Aug-99	Sediment Samples	87	ppm	000
SL-5	Cu	25-Aug-99	Sediment Samples	51	ppm	000
SL-5	Ni	19-Sep-99	Exchangeable Metals	2	ppm	<=W

Station	Parameter	Date	Description	Result	Units	Remark
SL-5	Ni	19-Sep-99	Metals Bound to Carbonates	2	ppm	<=W
SL-5	Ni	19-Sep-99	Metals Bound to Iron and Manganese	22	ppm	000
SL-5	Ni	19-Sep-99	Metals Bound to Organic Matter	14	ppm	000
SL-5	Ni	19-Sep-99	Residual Metals	25	ppm	000
SL-5	Ni	25-Aug-99	Sediment Samples	79	ppm	000
SL-5	Ni	25-Aug-99	Sediment Samples	112	ppm	000
SL-5	Ni	25-Aug-99	Sediment Samples	80	ppm	000
SL-5	Pb	19-Sep-99	Exchangeable Metals	4	ppm	<=W
SL-5	Pb	19-Sep-99	Metals Bound to Carbonates	6	ppm	000
SL-5	Pb	19-Sep-99	Metals Bound to Iron and Manganese	17	ppm	000
SL-5	Pb	19-Sep-99	Metals Bound to Organic Matter	8	ppm	000
SL-5	Pb	19-Sep-99	Residual Metals	40	ppm	000
SL-5	Pb	25-Aug-99	Sediment Samples	88	ppm	000
SL-5	Pb	25-Aug-99	Sediment Samples	102	ppm	000
SL-5	Pb	25-Aug-99	Sediment Samples	53	ppm	000
SL-5	Hg	19-Sep-99	Exchangeable Metals	0.01	ppm	<=W
SL-5	Hg	19-Sep-99	Metals Bound to Carbonates	0.01	ppm	<=W
SL-5	Hg	19-Sep-99	Metals Bound to Iron and Manganese	0.02	ppm	<=W
SL-5	Hg	19-Sep-99	Metals Bound to Organic Matter	0.02	ppm	<=W
SL-5	Hg	19-Sep-99	Residual Metals	0.16	ppm	000
SL-5	Hg	25-Aug-99	Sediment Samples	0.12	ppm	000
SL-5	Hg	25-Aug-99	Sediment Samples	0.03	ppm	000
SL-5	Hg	25-Aug-99	Sediment Samples	0.04	ppm	000
SL-5	U	19-Sep-99	Exchangeable Metals	0.2	ppm	000
SL-5	U	19-Sep-99	Metals Bound to Carbonates	0.9	ppm	000
SL-5	U	19-Sep-99	Metals Bound to Iron and Manganese	0.7	ppm	000
SL-5	U	19-Sep-99	Metals Bound to Organic Matter	0.2	ppm	000
SL-5	U	19-Sep-99	Residual Metals	1.1	ppm	000
SL-5	U	25-Aug-99	Sediment Samples	2.63	ppm	000
SL-5	U	25-Aug-99	Sediment Samples	3.3	ppm	000
SL-5	U	25-Aug-99	Sediment Samples	3.26	ppm	000
SL-5	Ag	19-Sep-99	Exchangeable Metals	0.3	ppm	<=W
SL-5	Ag	19-Sep-99	Metals Bound to Carbonates	0.3	ppm	<=W
SL-5	Ag	19-Sep-99	Metals Bound to Iron and Manganese	0.4	ppm	000
SL-5	Ag	19-Sep-99	Metals Bound to Organic Matter	0.3	ppm	<=W
SL-5	Ag	19-Sep-99	Residual Metals	0.1	ppm	<=W
SL-5	Ag	25-Aug-99	Sediment Samples	0.8	ppm	<=W
SL-5	Ag	25-Aug-99	Sediment Samples	0.8	ppm	<=W
SL-5	Ag	25-Aug-99	Sediment Samples	0.8	ppm	<=W
SL-5	Al	19-Sep-99	Exchangeable Metals	4	ppm	000
SL-5	Al	19-Sep-99	Metals Bound to Carbonates	70	ppm	000
SL-5	Al	19-Sep-99	Metals Bound to Iron and Manganese	842	ppm	000
SL-5	Al	19-Sep-99	Metals Bound to Organic Matter	2200	ppm	000
SL-5	Al	19-Sep-99	Residual Metals	43100	ppm	000
SL-5	Al	25-Aug-99	Sediment Samples	16200	ppm	000
SL-5	Al	25-Aug-99	Sediment Samples	15700	ppm	000
SL-5	Al	25-Aug-99	Sediment Samples	14400	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
SL-5	Ba	19-Sep-99	Exchangeable Metals	60.7	ppm	000
SL-5	Ba	19-Sep-99	Metals Bound to Carbonates	66	ppm	000
SL-5	Ba	19-Sep-99	Metals Bound to Iron and Manganese	85.8	ppm	000
SL-5	Ba	19-Sep-99	Metals Bound to Organic Matter	18.1	ppm	000
SL-5	Ba	19-Sep-99	Residual Metals	463	ppm	000
SL-5	Ba	25-Aug-99	Sediment Samples	190	ppm	000
SL-5	Ba	25-Aug-99	Sediment Samples	254	ppm	000
SL-5	Ba	25-Aug-99	Sediment Samples	239	ppm	000
SL-5	Be	19-Sep-99	Exchangeable Metals	0.04	ppm	<=W
SL-5	Be	19-Sep-99	Metals Bound to Carbonates	0.05	ppm	000
SL-5	Be	19-Sep-99	Metals Bound to Iron and Manganese	0.24	ppm	000
SL-5	Be	19-Sep-99	Metals Bound to Organic Matter	0.05	ppm	000
SL-5	Be	19-Sep-99	Residual Metals	1.08	ppm	000
SL-5	Be	25-Aug-99	Sediment Samples	0.8	ppm	000
SL-5	Be	25-Aug-99	Sediment Samples	0.8	ppm	000
SL-5	Be	25-Aug-99	Sediment Samples	0.7	ppm	000
SL-5	Bi	19-Sep-99	Exchangeable Metals	8	ppm	<=W
SL-5	Bi	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
SL-5	Bi	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
SL-5	Bi	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
SL-5	Bi	19-Sep-99	Residual Metals	0	ppm	ND
SL-5	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
SL-5	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
SL-5	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
SL-5	Ca	19-Sep-99	Exchangeable Metals	3110	ppm	000
SL-5	Ca	19-Sep-99	Metals Bound to Carbonates	1130	ppm	000
SL-5	Ca	19-Sep-99	Metals Bound to Iron and Manganese	1870	ppm	000
SL-5	Ca	19-Sep-99	Metals Bound to Organic Matter	289	ppm	000
SL-5	Ca	19-Sep-99	Residual Metals	11300	ppm	000
SL-5	Ca	25-Aug-99	Sediment Samples	8410	ppm	000
SL-5	Ca	25-Aug-99	Sediment Samples	8190	ppm	000
SL-5	Ca	25-Aug-99	Sediment Samples	6730	ppm	000
SL-5	Cd	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
SL-5	Cd	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
SL-5	Cd	19-Sep-99	Metals Bound to Iron and Manganese	1.5	ppm	000
SL-5	Cd	19-Sep-99	Metals Bound to Organic Matter	0.5	ppm	<=W
SL-5	Cd	19-Sep-99	Residual Metals	0.1	ppm	<=W
SL-5	Cd	25-Aug-99	Sediment Samples	2.7	ppm	000
SL-5	Cd	25-Aug-99	Sediment Samples	3.9	ppm	000
SL-5	Cd	25-Aug-99	Sediment Samples	2.2	ppm	000
SL-5	Cr	19-Sep-99	Exchangeable Metals	0.5	ppm	000
SL-5	Cr	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	<=W
SL-5	Cr	19-Sep-99	Metals Bound to Iron and Manganese	5.8	ppm	000
SL-5	Cr	19-Sep-99	Metals Bound to Organic Matter	5.6	ppm	000
SL-5	Cr	19-Sep-99	Residual Metals	42	ppm	000
SL-5	Cr	25-Aug-99	Sediment Samples	38	ppm	000
SL-5	Cr	25-Aug-99	Sediment Samples	36	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
SL-5	Cr	25-Aug-99	Sediment Samples	31	ppm	000
SL-5	Fe	19-Sep-99	Exchangeable Metals	21	ppm	000
SL-5	Fe	19-Sep-99	Metals Bound to Carbonates	2000	ppm	000
SL-5	Fe	19-Sep-99	Metals Bound to Iron and Manganese	16300	ppm	000
SL-5	Fe	19-Sep-99	Metals Bound to Organic Matter	4010	ppm	000
SL-5	Fe	19-Sep-99	Residual Metals	27900	ppm	000
SL-5	Fe	25-Aug-99	Sediment Samples	43800	ppm	000
SL-5	Fe	25-Aug-99	Sediment Samples	43800	ppm	000
SL-5	Fe	25-Aug-99	Sediment Samples	33000	ppm	000
SL-5	K	19-Sep-99	Exchangeable Metals	225	ppm	000
SL-5	K	19-Sep-99	Metals Bound to Carbonates	80	ppm	<=W
SL-5	K	19-Sep-99	Metals Bound to Iron and Manganese	100	ppm	<=W
SL-5	K	19-Sep-99	Metals Bound to Organic Matter	100	ppm	<=W
SL-5	K	19-Sep-99	Residual Metals	10000	ppm	000
SL-5	K	25-Aug-99	Sediment Samples	1640	ppm	000
SL-5	K	25-Aug-99	Sediment Samples	1340	ppm	000
SL-5	K	25-Aug-99	Sediment Samples	1280	ppm	000
SL-5	Mg	19-Sep-99	Exchangeable Metals	220	ppm	000
SL-5	Mg	19-Sep-99	Metals Bound to Carbonates	59	ppm	000
SL-5	Mg	19-Sep-99	Metals Bound to Iron and Manganese	755	ppm	000
SL-5	Mg	19-Sep-99	Metals Bound to Organic Matter	604	ppm	000
SL-5	Mg	19-Sep-99	Residual Metals	8360	ppm	000
SL-5	Mg	25-Aug-99	Sediment Samples	6510	ppm	000
SL-5	Mg	25-Aug-99	Sediment Samples	5880	ppm	000
SL-5	Mg	25-Aug-99	Sediment Samples	5530	ppm	000
SL-5	Mn	19-Sep-99	Exchangeable Metals	527	ppm	000
SL-5	Mn	19-Sep-99	Metals Bound to Carbonates	339	ppm	000
SL-5	Mn	19-Sep-99	Metals Bound to Iron and Manganese	487	ppm	000
SL-5	Mn	19-Sep-99	Metals Bound to Organic Matter	65.9	ppm	000
SL-5	Mn	19-Sep-99	Residual Metals	283	ppm	000
SL-5	Mn	25-Aug-99	Sediment Samples	1110	ppm	000
SL-5	Mn	25-Aug-99	Sediment Samples	883	ppm	000
SL-5	Mn	25-Aug-99	Sediment Samples	603	ppm	000
SL-5	Mo	19-Sep-99	Exchangeable Metals	2	ppm	<=W
SL-5	Mo	19-Sep-99	Metals Bound to Carbonates	1	ppm	<=W
SL-5	Mo	19-Sep-99	Metals Bound to Iron and Manganese	2	ppm	000
SL-5	Mo	19-Sep-99	Metals Bound to Organic Matter	2	ppm	<=W
SL-5	Mo	19-Sep-99	Residual Metals	5	ppm	<=W
SL-5	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
SL-5	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
SL-5	Mo	25-Aug-99	Sediment Samples	3	ppm	<=W
SL-5	Na	19-Sep-99	Exchangeable Metals	0	ppm	ND
SL-5	Na	19-Sep-99	Metals Bound to Carbonates	0	ppm	ND
SL-5	Na	19-Sep-99	Metals Bound to Iron and Manganese	0	ppm	ND
SL-5	Na	19-Sep-99	Metals Bound to Organic Matter	0	ppm	ND
SL-5	Na	19-Sep-99	Residual Metals	0	ppm	ND
SL-5	Na	25-Aug-99	Sediment Samples	224	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
SL-5	Na	25-Aug-99	Sediment Samples	169	ppm	000
SL-5	Na	25-Aug-99	Sediment Samples	171	ppm	000
SL-5	P	19-Sep-99	Exchangeable Metals	12	ppm	000
SL-5	P	19-Sep-99	Metals Bound to Carbonates	68	ppm	000
SL-5	P	19-Sep-99	Metals Bound to Iron and Manganese	210	ppm	000
SL-5	P	19-Sep-99	Metals Bound to Organic Matter	78	ppm	000
SL-5	P	19-Sep-99	Residual Metals	1740	ppm	000
SL-5	P	25-Aug-99	Sediment Samples	1540	ppm	000
SL-5	P	25-Aug-99	Sediment Samples	1460	ppm	000
SL-5	P	25-Aug-99	Sediment Samples	1090	ppm	000
SL-5	S	19-Sep-99	Exchangeable Metals	330	ppm	000
SL-5	S	19-Sep-99	Metals Bound to Carbonates	82	ppm	000
SL-5	S	19-Sep-99	Metals Bound to Iron and Manganese	458	ppm	000
SL-5	S	19-Sep-99	Metals Bound to Organic Matter	2760	ppm	000
SL-5	S	19-Sep-99	Residual Metals	0	ppm	ND
SL-5	S	25-Aug-99	Sediment Samples	0	ppm	ND
SL-5	S	25-Aug-99	Sediment Samples	0	ppm	ND
SL-5	S	25-Aug-99	Sediment Samples	0	ppm	ND
SL-5	Sb	19-Sep-99	Exchangeable Metals	8	ppm	<=W
SL-5	Sb	19-Sep-99	Metals Bound to Carbonates	11	ppm	000
SL-5	Sb	19-Sep-99	Metals Bound to Iron and Manganese	113	ppm	000
SL-5	Sb	19-Sep-99	Metals Bound to Organic Matter	29	ppm	000
SL-5	Sb	19-Sep-99	Residual Metals	0	ppm	ND
SL-5	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
SL-5	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
SL-5	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
SL-5	Se	19-Sep-99	Exchangeable Metals	8	ppm	<=W
SL-5	Se	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
SL-5	Se	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
SL-5	Se	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
SL-5	Se	19-Sep-99	Residual Metals	0	ppm	ND
SL-5	Se	25-Aug-99	Sediment Samples	0	ppm	ND
SL-5	Se	25-Aug-99	Sediment Samples	0	ppm	ND
SL-5	Se	25-Aug-99	Sediment Samples	0	ppm	ND
SL-5	Sr	19-Sep-99	Exchangeable Metals	35.1	ppm	000
SL-5	Sr	19-Sep-99	Metals Bound to Carbonates	15	ppm	000
SL-5	Sr	19-Sep-99	Metals Bound to Iron and Manganese	12.9	ppm	000
SL-5	Sr	19-Sep-99	Metals Bound to Organic Matter	2.5	ppm	000
SL-5	Sr	19-Sep-99	Residual Metals	171	ppm	000
SL-5	Sr	25-Aug-99	Sediment Samples	74	ppm	000
SL-5	Sr	25-Aug-99	Sediment Samples	71.6	ppm	000
SL-5	Sr	25-Aug-99	Sediment Samples	64.2	ppm	000
SL-5	Ti	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
SL-5	Ti	19-Sep-99	Metals Bound to Carbonates	1	ppm	000
SL-5	Ti	19-Sep-99	Metals Bound to Iron and Manganese	0.7	ppm	000
SL-5	Ti	19-Sep-99	Metals Bound to Organic Matter	1.2	ppm	000
SL-5	Ti	19-Sep-99	Residual Metals	3050	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
SL-5	Ti	25-Aug-99	Sediment Samples	568	ppm	000
SL-5	Ti	25-Aug-99	Sediment Samples	519	ppm	000
SL-5	Ti	25-Aug-99	Sediment Samples	541	ppm	000
SL-5	V	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
SL-5	V	19-Sep-99	Metals Bound to Carbonates	3.8	ppm	000
SL-5	V	19-Sep-99	Metals Bound to Iron and Manganese	15.3	ppm	000
SL-5	V	19-Sep-99	Metals Bound to Organic Matter	3.9	ppm	000
SL-5	V	19-Sep-99	Residual Metals	66	ppm	000
SL-5	V	25-Aug-99	Sediment Samples	55	ppm	000
SL-5	V	25-Aug-99	Sediment Samples	52	ppm	000
SL-5	V	25-Aug-99	Sediment Samples	43	ppm	000
SL-5	Zn	19-Sep-99	Exchangeable Metals	9.3	ppm	000
SL-5	Zn	19-Sep-99	Metals Bound to Carbonates	56.8	ppm	000
SL-5	Zn	19-Sep-99	Metals Bound to Iron and Manganese	306	ppm	000
SL-5	Zn	19-Sep-99	Metals Bound to Organic Matter	54.7	ppm	000
SL-5	Zn	19-Sep-99	Residual Metals	93	ppm	000
SL-5	Zn	25-Aug-99	Sediment Samples	814	ppm	000
SL-5	Zn	25-Aug-99	Sediment Samples	1240	ppm	000
SL-5	Zn	25-Aug-99	Sediment Samples	780	ppm	000
YC-1	As	19-Sep-99	Exchangeable Metals	125	ppm	000
YC-1	As	19-Sep-99	Metals Bound to Carbonates	512	ppm	000
YC-1	As	19-Sep-99	Metals Bound to Iron and Manganese	2800	ppm	000
YC-1	As	19-Sep-99	Metals Bound to Organic Matter	80	ppm	000
YC-1	As	19-Sep-99	Residual Metals	1120	ppm	000
YC-1	As	25-Aug-99	Sediment Samples	2050	ppm	000
YC-1	As	25-Aug-99	Sediment Samples	756	ppm	000
YC-1	As	25-Aug-99	Sediment Samples	259	ppm	000
YC-1	Co	19-Sep-99	Exchangeable Metals	131	ppm	000
YC-1	Co	19-Sep-99	Metals Bound to Carbonates	245	ppm	000
YC-1	Co	19-Sep-99	Metals Bound to Iron and Manganese	882	ppm	000
YC-1	Co	19-Sep-99	Metals Bound to Organic Matter	989	ppm	000
YC-1	Co	19-Sep-99	Residual Metals	170	ppm	000
YC-1	Co	25-Aug-99	Sediment Samples	1430	ppm	000
YC-1	Co	25-Aug-99	Sediment Samples	1540	ppm	000
YC-1	Co	25-Aug-99	Sediment Samples	1180	ppm	000
YC-1	Cu	19-Sep-99	Exchangeable Metals	6.5	ppm	000
YC-1	Cu	19-Sep-99	Metals Bound to Carbonates	39.9	ppm	000
YC-1	Cu	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	000
YC-1	Cu	19-Sep-99	Metals Bound to Organic Matter	1350	ppm	000
YC-1	Cu	19-Sep-99	Residual Metals	2480	ppm	000
YC-1	Cu	25-Aug-99	Sediment Samples	5800	ppm	000
YC-1	Cu	25-Aug-99	Sediment Samples	7760	ppm	000
YC-1	Cu	25-Aug-99	Sediment Samples	5300	ppm	000
YC-1	Ni	19-Sep-99	Exchangeable Metals	49	ppm	000
YC-1	Ni	19-Sep-99	Metals Bound to Carbonates	110	ppm	000
YC-1	Ni	19-Sep-99	Metals Bound to Iron and Manganese	454	ppm	000
YC-1	Ni	19-Sep-99	Metals Bound to Organic Matter	556	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
YC-1	Ni	19-Sep-99	Residual Metals	104	ppm	000
YC-1	Ni	25-Aug-99	Sediment Samples	1070	ppm	000
YC-1	Ni	25-Aug-99	Sediment Samples	1260	ppm	000
YC-1	Ni	25-Aug-99	Sediment Samples	937	ppm	000
YC-1	Pb	19-Sep-99	Exchangeable Metals	4	ppm	<=W
YC-1	Pb	19-Sep-99	Metals Bound to Carbonates	5	ppm	000
YC-1	Pb	19-Sep-99	Metals Bound to Iron and Manganese	9	ppm	000
YC-1	Pb	19-Sep-99	Metals Bound to Organic Matter	5	ppm	<=W
YC-1	Pb	19-Sep-99	Residual Metals	55	ppm	000
YC-1	Pb	25-Aug-99	Sediment Samples	99	ppm	000
YC-1	Pb	25-Aug-99	Sediment Samples	101	ppm	000
YC-1	Pb	25-Aug-99	Sediment Samples	42	ppm	000
YC-1	Hg	19-Sep-99	Exchangeable Metals	0.01	ppm	<=W
YC-1	Hg	19-Sep-99	Metals Bound to Carbonates	0.01	ppm	<=W
YC-1	Hg	19-Sep-99	Metals Bound to Iron and Manganese	0.02	ppm	<=W
YC-1	Hg	19-Sep-99	Metals Bound to Organic Matter	0.02	ppm	<=W
YC-1	Hg	19-Sep-99	Residual Metals	0.69	ppm	000
YC-1	Hg	25-Aug-99	Sediment Samples	0.8	ppm	000
YC-1	Hg	25-Aug-99	Sediment Samples	0.85	ppm	000
YC-1	Hg	25-Aug-99	Sediment Samples	0.56	ppm	000
YC-1	U	19-Sep-99	Exchangeable Metals	2.5	ppm	000
YC-1	U	19-Sep-99	Metals Bound to Carbonates	7.7	ppm	000
YC-1	U	19-Sep-99	Metals Bound to Iron and Manganese	8.7	ppm	000
YC-1	U	19-Sep-99	Metals Bound to Organic Matter	3.4	ppm	000
YC-1	U	19-Sep-99	Residual Metals	2.3	ppm	000
YC-1	U	25-Aug-99	Sediment Samples	30.3	ppm	000
YC-1	U	25-Aug-99	Sediment Samples	31.5	ppm	000
YC-1	U	25-Aug-99	Sediment Samples	16	ppm	000
YC-1	Ag	19-Sep-99	Exchangeable Metals	0.3	ppm	<=W
YC-1	Ag	19-Sep-99	Metals Bound to Carbonates	0.3	ppm	<=W
YC-1	Ag	19-Sep-99	Metals Bound to Iron and Manganese	0.3	ppm	<=W
YC-1	Ag	19-Sep-99	Metals Bound to Organic Matter	0.3	ppm	<=W
YC-1	Ag	19-Sep-99	Residual Metals	3	ppm	000
YC-1	Ag	25-Aug-99	Sediment Samples	6.2	ppm	000
YC-1	Ag	25-Aug-99	Sediment Samples	6.7	ppm	000
YC-1	Ag	25-Aug-99	Sediment Samples	2.9	ppm	000
YC-1	Al	19-Sep-99	Exchangeable Metals	9	ppm	000
YC-1	Al	19-Sep-99	Metals Bound to Carbonates	184	ppm	000
YC-1	Al	19-Sep-99	Metals Bound to Iron and Manganese	1370	ppm	000
YC-1	Al	19-Sep-99	Metals Bound to Organic Matter	3360	ppm	000
YC-1	Al	19-Sep-99	Residual Metals	34900	ppm	000
YC-1	Al	25-Aug-99	Sediment Samples	15500	ppm	000
YC-1	Al	25-Aug-99	Sediment Samples	16200	ppm	000
YC-1	Al	25-Aug-99	Sediment Samples	18300	ppm	000
YC-1	Ba	19-Sep-99	Exchangeable Metals	43.6	ppm	000
YC-1	Ba	19-Sep-99	Metals Bound to Carbonates	47.6	ppm	000
YC-1	Ba	19-Sep-99	Metals Bound to Iron and Manganese	73.1	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
YC-1	Ba	19-Sep-99	Metals Bound to Organic Matter	9.8	ppm	000
YC-1	Ba	19-Sep-99	Residual Metals	424	ppm	000
YC-1	Ba	25-Aug-99	Sediment Samples	115	ppm	000
YC-1	Ba	25-Aug-99	Sediment Samples	168	ppm	000
YC-1	Ba	25-Aug-99	Sediment Samples	331	ppm	000
YC-1	Be	19-Sep-99	Exchangeable Metals	0.04	ppm	<=W
YC-1	Be	19-Sep-99	Metals Bound to Carbonates	0.28	ppm	000
YC-1	Be	19-Sep-99	Metals Bound to Iron and Manganese	1.11	ppm	000
YC-1	Be	19-Sep-99	Metals Bound to Organic Matter	0.28	ppm	000
YC-1	Be	19-Sep-99	Residual Metals	0.98	ppm	000
YC-1	Be	25-Aug-99	Sediment Samples	2.4	ppm	000
YC-1	Be	25-Aug-99	Sediment Samples	2.5	ppm	000
YC-1	Be	25-Aug-99	Sediment Samples	2.7	ppm	000
YC-1	Bi	19-Sep-99	Exchangeable Metals	8	ppm	<=W
YC-1	Bi	19-Sep-99	Metals Bound to Carbonates	17	ppm	000
YC-1	Bi	19-Sep-99	Metals Bound to Iron and Manganese	20	ppm	000
YC-1	Bi	19-Sep-99	Metals Bound to Organic Matter	167	ppm	000
YC-1	Bi	19-Sep-99	Residual Metals	0	ppm	ND
YC-1	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
YC-1	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
YC-1	Bi	25-Aug-99	Sediment Samples	0	ppm	ND
YC-1	Ca	19-Sep-99	Exchangeable Metals	4770	ppm	000
YC-1	Ca	19-Sep-99	Metals Bound to Carbonates	2120	ppm	000
YC-1	Ca	19-Sep-99	Metals Bound to Iron and Manganese	1670	ppm	000
YC-1	Ca	19-Sep-99	Metals Bound to Organic Matter	489	ppm	000
YC-1	Ca	19-Sep-99	Residual Metals	5540	ppm	000
YC-1	Ca	25-Aug-99	Sediment Samples	8520	ppm	000
YC-1	Ca	25-Aug-99	Sediment Samples	9000	ppm	000
YC-1	Ca	25-Aug-99	Sediment Samples	8870	ppm	000
YC-1	Cd	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
YC-1	Cd	19-Sep-99	Metals Bound to Carbonates	0.5	ppm	000
YC-1	Cd	19-Sep-99	Metals Bound to Iron and Manganese	0.6	ppm	000
YC-1	Cd	19-Sep-99	Metals Bound to Organic Matter	0.5	ppm	<=W
YC-1	Cd	19-Sep-99	Residual Metals	0.1	ppm	<=W
YC-1	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
YC-1	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
YC-1	Cd	25-Aug-99	Sediment Samples	0.3	ppm	<=W
YC-1	Cr	19-Sep-99	Exchangeable Metals	0.5	ppm	000
YC-1	Cr	19-Sep-99	Metals Bound to Carbonates	4.8	ppm	000
YC-1	Cr	19-Sep-99	Metals Bound to Iron and Manganese	41.1	ppm	000
YC-1	Cr	19-Sep-99	Metals Bound to Organic Matter	76.6	ppm	000
YC-1	Cr	19-Sep-99	Residual Metals	39	ppm	000
YC-1	Cr	25-Aug-99	Sediment Samples	184	ppm	000
YC-1	Cr	25-Aug-99	Sediment Samples	177	ppm	000
YC-1	Cr	25-Aug-99	Sediment Samples	52	ppm	000
YC-1	Fe	19-Sep-99	Exchangeable Metals	31	ppm	000
YC-1	Fe	19-Sep-99	Metals Bound to Carbonates	1310	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
YC-1	Fe	19-Sep-99	Metals Bound to Iron and Manganese	11100	ppm	000
YC-1	Fe	19-Sep-99	Metals Bound to Organic Matter	2690	ppm	000
YC-1	Fe	19-Sep-99	Residual Metals	26200	ppm	000
YC-1	Fe	25-Aug-99	Sediment Samples	27300	ppm	000
YC-1	Fe	25-Aug-99	Sediment Samples	26300	ppm	000
YC-1	Fe	25-Aug-99	Sediment Samples	21400	ppm	000
YC-1	K	19-Sep-99	Exchangeable Metals	188	ppm	000
YC-1	K	19-Sep-99	Metals Bound to Carbonates	80	ppm	<=W
YC-1	K	19-Sep-99	Metals Bound to Iron and Manganese	100	ppm	<=W
YC-1	K	19-Sep-99	Metals Bound to Organic Matter	100	ppm	<=W
YC-1	K	19-Sep-99	Residual Metals	10200	ppm	000
YC-1	K	25-Aug-99	Sediment Samples	1040	ppm	000
YC-1	K	25-Aug-99	Sediment Samples	871	ppm	000
YC-1	K	25-Aug-99	Sediment Samples	812	ppm	000
YC-1	Mg	19-Sep-99	Exchangeable Metals	205	ppm	000
YC-1	Mg	19-Sep-99	Metals Bound to Carbonates	56	ppm	000
YC-1	Mg	19-Sep-99	Metals Bound to Iron and Manganese	101	ppm	000
YC-1	Mg	19-Sep-99	Metals Bound to Organic Matter	375	ppm	000
YC-1	Mg	19-Sep-99	Residual Metals	5960	ppm	000
YC-1	Mg	25-Aug-99	Sediment Samples	4010	ppm	000
YC-1	Mg	25-Aug-99	Sediment Samples	4000	ppm	000
YC-1	Mg	25-Aug-99	Sediment Samples	3800	ppm	000
YC-1	Mn	19-Sep-99	Exchangeable Metals	168	ppm	000
YC-1	Mn	19-Sep-99	Metals Bound to Carbonates	111	ppm	000
YC-1	Mn	19-Sep-99	Metals Bound to Iron and Manganese	88.9	ppm	000
YC-1	Mn	19-Sep-99	Metals Bound to Organic Matter	20.9	ppm	000
YC-1	Mn	19-Sep-99	Residual Metals	182	ppm	000
YC-1	Mn	25-Aug-99	Sediment Samples	273	ppm	000
YC-1	Mn	25-Aug-99	Sediment Samples	222	ppm	000
YC-1	Mn	25-Aug-99	Sediment Samples	179	ppm	000
YC-1	Mo	19-Sep-99	Exchangeable Metals	2	ppm	<=W
YC-1	Mo	19-Sep-99	Metals Bound to Carbonates	1	ppm	<=W
YC-1	Mo	19-Sep-99	Metals Bound to Iron and Manganese	2	ppm	<=W
YC-1	Mo	19-Sep-99	Metals Bound to Organic Matter	2	ppm	<=W
YC-1	Mo	19-Sep-99	Residual Metals	5	ppm	<=W
YC-1	Mo	25-Aug-99	Sediment Samples	5	ppm	000
YC-1	Mo	25-Aug-99	Sediment Samples	3	ppm	000
YC-1	Mo	25-Aug-99	Sediment Samples	3	ppm	000
YC-1	Na	19-Sep-99	Exchangeable Metals	0	ppm	ND
YC-1	Na	19-Sep-99	Metals Bound to Carbonates	0	ppm	ND
YC-1	Na	19-Sep-99	Metals Bound to Iron and Manganese	0	ppm	ND
YC-1	Na	19-Sep-99	Metals Bound to Organic Matter	0	ppm	ND
YC-1	Na	19-Sep-99	Residual Metals	0	ppm	ND
YC-1	Na	25-Aug-99	Sediment Samples	157	ppm	000
YC-1	Na	25-Aug-99	Sediment Samples	155	ppm	000
YC-1	Na	25-Aug-99	Sediment Samples	152	ppm	000
YC-1	P	19-Sep-99	Exchangeable Metals	9	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
YC-1	P	19-Sep-99	Metals Bound to Carbonates	29	ppm	000
YC-1	P	19-Sep-99	Metals Bound to Iron and Manganese	116	ppm	000
YC-1	P	19-Sep-99	Metals Bound to Organic Matter	99	ppm	000
YC-1	P	19-Sep-99	Residual Metals	1660	ppm	000
YC-1	P	25-Aug-99	Sediment Samples	1400	ppm	000
YC-1	P	25-Aug-99	Sediment Samples	1600	ppm	000
YC-1	P	25-Aug-99	Sediment Samples	1760	ppm	000
YC-1	S	19-Sep-99	Exchangeable Metals	1240	ppm	000
YC-1	S	19-Sep-99	Metals Bound to Carbonates	315	ppm	000
YC-1	S	19-Sep-99	Metals Bound to Iron and Manganese	1150	ppm	000
YC-1	S	19-Sep-99	Metals Bound to Organic Matter	9330	ppm	000
YC-1	S	19-Sep-99	Residual Metals	0	ppm	ND
YC-1	S	25-Aug-99	Sediment Samples	0	ppm	ND
YC-1	S	25-Aug-99	Sediment Samples	0	ppm	ND
YC-1	S	25-Aug-99	Sediment Samples	0	ppm	ND
YC-1	Sb	19-Sep-99	Exchangeable Metals	8	ppm	<=W
YC-1	Sb	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
YC-1	Sb	19-Sep-99	Metals Bound to Iron and Manganese	75	ppm	000
YC-1	Sb	19-Sep-99	Metals Bound to Organic Matter	26	ppm	000
YC-1	Sb	19-Sep-99	Residual Metals	0	ppm	ND
YC-1	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
YC-1	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
YC-1	Sb	25-Aug-99	Sediment Samples	0	ppm	ND
YC-1	Se	19-Sep-99	Exchangeable Metals	8	ppm	<=W
YC-1	Se	19-Sep-99	Metals Bound to Carbonates	8	ppm	<=W
YC-1	Se	19-Sep-99	Metals Bound to Iron and Manganese	10	ppm	<=W
YC-1	Se	19-Sep-99	Metals Bound to Organic Matter	10	ppm	<=W
YC-1	Se	19-Sep-99	Residual Metals	0	ppm	ND
YC-1	Se	25-Aug-99	Sediment Samples	0	ppm	ND
YC-1	Se	25-Aug-99	Sediment Samples	0	ppm	ND
YC-1	Se	25-Aug-99	Sediment Samples	0	ppm	ND
YC-1	Sr	19-Sep-99	Exchangeable Metals	29.2	ppm	000
YC-1	Sr	19-Sep-99	Metals Bound to Carbonates	15	ppm	000
YC-1	Sr	19-Sep-99	Metals Bound to Iron and Manganese	14.9	ppm	000
YC-1	Sr	19-Sep-99	Metals Bound to Organic Matter	4.6	ppm	000
YC-1	Sr	19-Sep-99	Residual Metals	97	ppm	000
YC-1	Sr	25-Aug-99	Sediment Samples	55.2	ppm	000
YC-1	Sr	25-Aug-99	Sediment Samples	57.7	ppm	000
YC-1	Sr	25-Aug-99	Sediment Samples	53.8	ppm	000
YC-1	Ti	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
YC-1	Ti	19-Sep-99	Metals Bound to Carbonates	1.1	ppm	000
YC-1	Ti	19-Sep-99	Metals Bound to Iron and Manganese	1.6	ppm	000
YC-1	Ti	19-Sep-99	Metals Bound to Organic Matter	1.3	ppm	000
YC-1	Ti	19-Sep-99	Residual Metals	2510	ppm	000
YC-1	Ti	25-Aug-99	Sediment Samples	297	ppm	000
YC-1	Ti	25-Aug-99	Sediment Samples	270	ppm	000
YC-1	Ti	25-Aug-99	Sediment Samples	262	ppm	000

Station	Parameter	Date	Description	Result	Units	Remark
YC-1	V	19-Sep-99	Exchangeable Metals	0.5	ppm	<=W
YC-1	V	19-Sep-99	Metals Bound to Carbonates	1.7	ppm	000
YC-1	V	19-Sep-99	Metals Bound to Iron and Manganese	10.3	ppm	000
YC-1	V	19-Sep-99	Metals Bound to Organic Matter	4.8	ppm	000
YC-1	V	19-Sep-99	Residual Metals	47	ppm	000
YC-1	V	25-Aug-99	Sediment Samples	42	ppm	000
YC-1	V	25-Aug-99	Sediment Samples	41	ppm	000
YC-1	V	25-Aug-99	Sediment Samples	40	ppm	000
YC-1	Zn	19-Sep-99	Exchangeable Metals	11	ppm	000
YC-1	Zn	19-Sep-99	Metals Bound to Carbonates	32.5	ppm	000
YC-1	Zn	19-Sep-99	Metals Bound to Iron and Manganese	79.6	ppm	000
YC-1	Zn	19-Sep-99	Metals Bound to Organic Matter	41.5	ppm	000
YC-1	Zn	19-Sep-99	Residual Metals	82	ppm	000
YC-1	Zn	25-Aug-99	Sediment Samples	196	ppm	000
YC-1	Zn	25-Aug-99	Sediment Samples	223	ppm	000
YC-1	Zn	25-Aug-99	Sediment Samples	200	ppm	000

Remarks	Description
000	Measured Amount
<=W	No measurable response (zero) < reported value
ND	No data

Appendix II.6 Ministry of Labour Radiation Protection Monitoring Service Methods

Ontario

Ministry of Labour
Ministère du Travail de l'Ontario

Radiation Protection Service
81A Resources Rd
Weston, ON,
M9P 3T1

The Radiation Protection Monitoring Service (previously know as the Radiation Protection Laboratory) has been supplying radioanalytical service to Ontario Government Ministries since the late 1960's. The Service is primarily charged with maintaining a network of monitoring stations around Ontario and adjacent reactor sites (such as the Fermi 2 reactor adjacent to Windsor). The Service acts as the lead agency of the Ingestion Monitoring Organisation as defined in the Province of Ontario's Nuclear Emergency Plan. Historically, the Service has provided analytical data to the MOE from monitoring of the environment around uranium mining and milling areas and this comprised a high percentage of the work done by the Service prior to MOE discontinuing much of these studies in the late 1980's.

Soil samples analyzed by the Radiation Protection Monitoring Service for the MOE during calendar years 1998/1999 included 80 samples submitted for the Deloro Residential Properties Study in 1998 (Report No:/98-0326), 6 samples of Deloro Garden Soil (Report No.:/98-0327) and 64 samples submitted for the Moira River Study in 1999 (Report No.:/99-0179).

Samples were handled as per routine sample handling practices including the following analytical progression.

The soil samples were all dried and ground. 25 grams of each was transferred to a jar and sealed for 30 days.

Samples were counted by gamma spectrometry using high purity Germanium detectors for 10,000 seconds each. Background peaks were subtracted and analyses were performed using Canberra Genie PC software. Reported results were on an "as received" basis.

Instrumental energy calibration is regularly checked against mixed radionuclide gamma-ray reference sources prepared with solutions supplied by Amersham International and tracible to NIST by certificate of calibration.

Detectors were standardized against a similar geometry spiked with mixed radionuclide gamma-ray reference solution supplied by Amersham International and tracible to NIST by certificate of calibration.

In terms of quality assurance programs, the Service generates routine internal blind samples in all matrices analyzed and participates in Intercomparison Programs with the IAEA, the US. EPA (until the program was discontinued in late 1998) and the US. Environmental Measurements Laboratory (since 1998).

Ken Gilmer
Manager, Radiation Protection Monitoring Service
11-April-2000

CALIBRATION OF GAMMA DETECTOR: RPL-00
DETERMINATION OF COUNTING EFFICIENCY FOR GAMMA EMITTERS

Radiation Protection Laboratory
Instrument Calibration

1.0 Purpose:

To determine the counting efficiency of germanium detectors for various gamma emitters.

2.0 Scope:

An energy efficiency curve is determined annually for each germanium detector system and for each sample geometry with a multiline reference source.

The common geometries are:

1. 4-L Marinelli beaker for 3-L liquid samples
2. 1-L Marinelli beaker for 1-L samples
3. 100-mL or 50-mL plastic container for 25-g solid samples
4. charcoal cartridges
5. air filter, 8"x10", 6"x8" active area, folded once and placed in a filter envelope
6. several filters together, dimensions as in #4
7. point sources

A gamma ray standard source consisting of gamma emitters that emit gamma rays with energies from about 100 to 1500 keV is dispensed uniformly into the calibration sample. The nuclides generally used and their corresponding gamma energies are:

americium-241	59.54 keV
cadmium-109	88.03
cobalt-57	122.1
cerium-139	165.9

mercury-203			279.2
tin-113			391.7
strontium-85			514.0
cesium-137		661.7	
yttrium-88		898.0	
		1836	
cobalt-60	1173		
		1333	

3.0 Responsibilities:

This procedure is for the use of qualified personnel of the Radiation Protection Laboratory.

4.0 Special Definitions:

N/A

5.0 Work Instruction Steps:

Preparation of Reference Sources

Critical Control Point: The reference sources should be
properly labeled and kept in a designated area.

Water, 1 L

1 Place about 500 mL of distilled water into a 1-L volumetric flask.
2 Add an accurately measured amount of mixed gamma emitters.
3 Add inactive diluent or available appropriate carriers to make the nuclide concentration approximately 25 mg/L.
4 Mix by shaking the solution.
5 Dilute to volume with distilled water.
6 Mix thoroughly.
7 Transfer the solution totally into a 1-L Marinelli beaker.

Water, 3 L

1 Place about 1500 mL distilled water into a 2-L volumetric flask.
2 Add an accurately measured amount of mixed gamma emitters.
3 Add available appropriate carriers to make the nuclide concentration approximately 25 mg/L.
4 Mix by shaking the solution.
5 Dilute to volume with distilled water.
6 Mix thoroughly.
7 Transfer quantitatively into a 4-L Marinelli beaker, using 1 L of distilled water to rinse the flask and adding the rinse to the solution in the beaker, making the total volume of the solution 3 L.

Soil

Critical Control Point: Sometimes, a solid standard is used to prepare spiked soil; e.g. standard pitchblende for uranium measurement or standard monazite for thorium measurement. In this case, weigh the standard into a plastic container, add small portions of dried, sieved soil and mix thoroughly, until the total weight is 25 g.

1 Weigh 25 g of dried, sieved soil into a 250-mL Teflon beaker.
2 Pipet a measured amount of mixed gamma emitters into a plastic beaker and dilute with water to less than 1 M.

Critical Control Points: If the reference source is to be used for radium-226 determinations, use radium-226 standard solution instead of mixed gamma emitters.

The standard is diluted to prevent excessive chemical reaction between soil components and the acid in the standard solution.

3 Carefully and quantitatively transfer the standard solution into a crater in the soil.
4 Gently shake the beaker to allow the soil to cover the dampened crater.
5 Carefully add distilled water to thoroughly wet the soil, while stirring the mixture with a glass rod.
6 Allow the soil to dry under an IR lamp, stirring the mixture occasionally.

Critical Control Point: Stirring is done to prevent baking of the surface layer, to expose the wet soil layers underneath and to break down clumps of soil that may form.

6 Transfer the dried spiked soil into an appropriate plastic container.
7 Weigh the soil.

Critical Control Point: If the weight is not 25 g, add dried, sieved soil and mix thoroughly.

8 Pack the soil into the container by tapping the container against a hard surface while rotating it and stamping on the sample surface with the bottom of a small beaker.

Critical Control Point: If the reference source contains radium-226 standard, seal the source with paraffin, using a little melted wax at a time and allowing it to cool, until the container is filled. Allow radon-222 to come to equilibrium before using the reference source.

Filter

1 Mark a 6"x8" area on the filter by drawing a one-inch margin all around.
2 Place a plastic sheet under the filter.
3 Pipet a measured amount of mixed gamma emitters into a 25-mL beaker.

4 With a capillary dropper, distribute the standard solution uniformly over the active area of the filter.

Critical Control Point: To aid in the uniform distribution of the gamma standard, draw a grid on the active area of the filter and drop equal amounts of the standard solution on the grid spaces.

5 Rinse the beaker with inactive diluent or with distilled water containing carrier solution having nuclide concentrations of 25 ug/mL.
6 Distribute the rinse uniformly over the active area of the filter.
7 Allow the filter to dry uniformly under an IR lamp.
8 Wrap the filter with the plastic sheet.
9 Fold the filter in half and place it inside a filter envelope.

Charcoal Cartidge, face-loaded

1 With a capillary pipet, distribute a measured amount of mixed gamma emitters uniformly on the active surface of the charcoal cartidge.

2 Allow to dry naturally.

3 Cover the cartridge.

Point Source

1 Carefully drop a measured microliter amount of mixed gamma emitters at the center of a stainless steel planchet (or desired container).

2 Dry the solution carefully under an IR lamp.

3 Repeat steps 1 and 2 until the desired amount of standard has been evaporated.

4 Place the planchet in a labeled source holder.

Efficiency Calibration

1 Place the reference source with the desired geometry on the detector.

Critical Control Point: A source holder should be used for the filters in order to ensure reproducible counting on a routine basis.

2 Follow the procedure for efficiency calibration given in the instrument manual.

6.0 Associated Documents:

References

"Quality Control for Environmental Measurements Using Gamma-Ray Spectrometry", Ziegler, Lee, H. and Hunt, Hiram, M., PB-277 377, U.S. Department of Commerce, National Technical Information Series, Environmental Monitoring and Support Lab, Las Vegas, Nevada, December 1977, Calibration of the System, pp. 40-44.

"Handbook for Analytical Quality Control in Radioanalytical Laboratories", Kanipe, Larry G., E-EP/77-4, EPA-600/7-77-088, Office of energy, Minerals and Industry, U.S. Environmental Protection Agency, Washington, DC, August 1977, Quality Control of Counting Equipment, pp. 3-7 and 3-11.

"Preparation and Analysis of High-Quality Spiked Soil Standards", Olson, Dale G. and Bernabee, Roger B., Health Physics, 1988, 54(4), pp. 451-459.

Instrument Manuals
gamma spectrometers

DETERMINATION OF GAMMA EMITTERS RPL-00
Radiation Protection Laboratory / /98
Quality Procedure

1.0 Summary:

A gamma ray from a sample in a Marinelli beaker or a suitable container interacts with the scintillator of the gamma detector producing light. The light falls on a photocathode causing ejection of electrons which are multiplied and registered as a measurable current pulse, the amplitude of which is proportional to the energy deposited in the scintillator by the gamma ray. Signals from the detector are amplified and fed into a multichannel analyzer which sorts the electrical pulses according to their magnitude and records each in appropriate channels.

In a sample spectrum, the pulses are registered as full energy peaks or photopeaks. A sample containing several gamma emitters will give a spectrum with photopeaks characteristic of each nuclide. Qualitative analysis is made by referring to a calibration curve of known energies vs. channel number of the analyzer. The area under each photopeak is a measure of the amount of nuclide present in the sample.

2.0 Scope:

Fission and activation products from nuclear reactors and atomic bomb explosions are commonly beta-gamma emitters. Determination of these radionuclides gives a measure of the extent of releases from reactors or bombs or of the remaining fallout. The most common of these gamma emitters determined in environmental samples are iodine-131, cesium-137, cesium-134, cobalt-60.

Some naturally occurring radionuclides emit gamma rays; e.g. beryllium-7, potassium-40, uranium-235, thorium-234, radium-226, lead-214, bismuth-214, actinium-228, lead-212, bismuth-212, thallium-208, lead-210.

A sample spectrum may be complicated by Compton edges, annihilation peak, escape peaks due to photons not absorbed in the crystal, backscatter peaks due to photons scattered by the surrounding material, and sum peaks.

A practical limit of detection of 300 mBq/L is applied to routine liquid samples; i.e. water samples from monitoring areas around nuclear facilities, in which fission and activation products are usually not detected.

Health and Welfare Canada has set the maximum acceptable concentrations of some gamma emitters in drinking water.

Nuclide	Max. acceptable concentration Bq/L
cesium-134	7
cesium-137	10
cobalt-60	2
iodine-131	6

3.0 Responsibilities:

This procedure is for the use of qualified personnel of the Radiation Protection Laboratory.

4.0 Definitions:

N/A

5.0 Procedure:

5.1 Safety

Follow general laboratory safety procedures as practised in Ontario Region laboratories and radiation laboratories.

5.2 Equipment/Materials

1 gamma spectrometer assembly
2 analytical balance
3 Marinelli flasks
4 cylinders
5 plastic jars or bottles
6 plastic sheet

5.3 Reagents

paraffin

5.4 Process

Critical Control Point: Run blanks and spiked or control samples, as necessary.

Sample Preparation

Critical Control Point: The samples should be placed in suitable container, their geometries simulating those of matrices for which efficiency calibration curves have been previously prepared.

1 Measure 3 L of liquid sample (water, milk or urine) into a Marinelli flask.

Critical Control Point: For smaller samples, use small Marinelli flasks or plastic bottles.

2 Weigh 25 g of soil or sediment into a plastic jar.

Critical Control Point: If radium-226 is to be determined, seal the packed sample with paraffin and allow radon-222 to come to equilibrium.

3 Wrap air filters and iodine cartridges with plastic.

Counting

1 Position the sample on the detector.
2 Count the sample for a suitable period; e.g. 10000 s for 3-L liquids and 25-g solids, 60000 s (overnight) for 0.5-L liquids, filters and iodine cartridges.
3 Count a corresponding blank.
4 Identify the nuclides present from the gamma peaks in the sample spectrum.
5 Determine the areas of the gamma peaks.

Critical Control Point: The computer-controlled gamma spectrometer assembly is programmed to print out the nuclides and their net activities in their desired units, as well as the counting errors.

Manual calculations are as follows:

$$\begin{aligned} Bq &= NPA \times 1/a \times 1/D \times 1/E \\ Bq/L &= NPA \times 1/a \times 1/D \times 1/E \times 1/V \\ Bq/g &= NPA \times 1/a \times 1/D \times 1/E \times 1/W \end{aligned}$$

where NPA = net peak area in cps

a = gamma abundance

D = decay factor from sampling time

E = gamma counting efficiency

V = volume of sample in liters

W = weight of sample in grams

For potassium measurements,

g K per liter = Bq K per liter x 1/30.52

where 30.52 is Bq per gram of natural potassium.

5.5 Quality Control/Results Verification

The following are used as the corresponding blanks: distilled water which has been allowed to stand for sometime for radon and thoron daughters to decay, 25 g sodium chloride, clean filter or filters, cartridge and planchet.

The counting efficiency for each peak is determined from a calibration curve of efficiency vs. energy for a particular matrix or geometry.

Samples with high counts or those which do not follow monitoring trends are recounted or re-analyzed, as necessary.

Calculation of detection limit is as follows:

a. for routine liquid samples, e.g. water samples from monitoring areas around reactor facilities, in which fission and activation products are usually not detected, the practical limit should be used. This is 300 mBq/L for the isotopes iodine-131, cesium-137, cesium-134 nad cobalt-60, in one- or three-liter samples counted for 10,000 s.

b. other samples should be considered as special samples and therefore, treated differently: counts in the Compton background under each energy peak, plus the net peak area (if peaks are observed), in the corresponding spectrum of the blank are to be used in the calculation of L_d.

$$L_d(\text{counts}) = 2.71 + 4.65 \times (R_b \times T)^{1/2}$$
$$L_d(\text{cps}) = L_d(\text{counts})/T$$
$$L_d(\text{Bq}) = L_d(\text{cps}) \times 1/a \times 1/E$$

where R_b = background cps
T = counting time in seconds
a = gamma abundance
E = counting efficiency

c. detection limits for air filters and iodine cartridges are to be calculated as in b until average figures (practical limits), based on the Compton background counts in routine sample spectra, are established.

5.o Method Validation

N/A

6.0 Associated Documents:

6.1 References

"Prescribed Procedures for the Measurement of Radioactivity in Drinking Water", Krieger, Herman L. and Whittaker, Earl L., EPA-600-4-80-032, Environmental Monitoring and Support Laboratory, U.S Environmental Protection Agency, Cincinnati, Ohio, August 1980, Gross Alpha and Beta Activity, Section 4, Gamma Emitting Radionuclides in Drinking Water, pp. 21-25.

"Guidelines for Canadian Drinking Water Quality, Health and Welfare Canada, 6th edition. Published by authority of the Minister of Health, 1996, p. 82.

"Measurements Using Potassium", Memorandum from J. Lee dated Feb. 4, 1988, based on "Experience Gained through Intercomparison of Long-lived Radionuclide Measurements on Marine environmental Matrices", J. Radioanal. and Nucl. Chem., 1987, 115(1), pp.175-189.

"Rules for Calculating and Reporting Detection Limits", from Manual of Procedures, Radiation Protection Laboratory.

Instrument Manuals
gamma spectrometer assemblies

6.2 Bibliography

"Handbook of Radioanalytical Chemistry", Tolgyessy, Juraj and Bujdoso, Erno, (eds), CRC Press, Boca Raton, 1991.

"EML Procedures Manual, HASL-300", Chieco, Nancy A., Bogen, Donald C. and Knutson, Earl O. (eds), Environmental Measurements Laboratory, U.S. Department of Energy, New York, November 1990, rev. February 1992.

"Radioisotope Techniques", Overman, Ralph T. and Clark, Herbert, M., McGraw-Hill Book Co., Inc., New York, 1960.

"Limits for Qualitative Detection and Quantitative Determination", Currie, Lloyd, Anal. Chem. 1968, 40, pp. 586-593.

Appendix II.7 Radionuclide Activities in Sediment Samples from the Moira River System

Soil Samples Submitted by MOE as Part of the 1999 Moira River Study

Region: Eastern **Area: Moira R.**

Smp No.	Sampling Date	Station No.	Location	Moisture %	Ra-226 Bq/g	Ra-228 Bq/g	Th-228 Bq/g	U-238 Bq/g
001	30 Apr 99	M-01	STN MR-R1	35	0.02	<0.05	<0.01	<0.10
002	30 Apr 99	M-02	STN MR-R2	37	<0.01	<0.05	<0.01	<0.10
003	28 Apr 99	M-03	STN MR-1	54	<0.01	<0.05	<0.01	<0.10
004	30 Apr 99	M-04	STN MR-2	56	<0.01	<0.05	<0.01	<0.10
005	28 Apr 99	M-05	STN MR-3	48	0.01	<0.05	<0.01	<0.10
006	28 Apr 99	M-06	STN MR-4	46	0.01	<0.05	<0.01	<0.10
007	30 Apr 99	M-07	STN MR-5	71	<0.01	<0.05	<0.01	<0.10
008	27 Apr 99	M-08	STN ABOVE BEND BAY	79	<0.01	<0.05	<0.01	<0.10
009	27 Apr 99	M-09	STN BEND BAY	89	<0.01	<0.05	<0.01	<0.10
010	27 Apr 99	M-10	STN MR-7	53	0.01	<0.05	<0.01	<0.10
011	27 Apr 99	M-11	MOIRA R. AT LATTA	55	0.01	<0.05	<0.01	<0.10
012	29 Apr 99	M-12	MOIRA R. AT CHISHOLM'S MILL	82	<0.01	<0.05	<0.01	<0.10
013	22 Apr 99	M-13	MOIRA L. STN ML-1	92	<0.01	<0.05	<0.01	<0.10
014	22 Apr 99	M-14	MOIRA L. STN ML-2	93	<0.01	<0.05	<0.01	<0.10
015	26 Apr 99	M-15	MOIRA L. STN ML-3	97	<0.01	<0.05	<0.01	<0.10
016	27 Apr 99	M-16	MOIRA L. STN ML-5	85	<0.01	<0.05	<0.01	<0.10
017	27 Apr 99	M-17	MOIRA L. STN ML-5	83	<0.01	<0.05	<0.01	<0.10
018	22 Apr 99	M-18	MOIRA L. STN ML-1A	89	<0.01	<0.05	<0.01	<0.10
019	22 Apr 99	M-19	MOIRA L. STN ML-A 2M	84	<0.01	<0.05	<0.01	<0.10
020	22 Apr 99	M-20	MOIRA L. STN ML-2A 1M	33	<0.01	<0.05	<0.01	<0.10
021	22 Apr 99	M-21	MOIRA L. STN ML-2A 2M	78	<0.01	<0.05	<0.01	<0.10
022	27 Apr 99	M-22	MOIRA L. STN ML-3A 1M	31	<0.01	<0.05	<0.01	<0.10
023	27 Apr 99	M-23	MOIRA L. STN ML-3A 2M	35	<0.01	<0.05	<0.01	<0.10
024	27 Apr 99	M-24	MOIRA L. STN ML-3B 1M	78	<0.01	<0.05	<0.01	<0.10
025	27 Apr 99	M-25	MOIRA L. STN ML-3B 2M	86	<0.01	<0.05	<0.01	<0.10
026	27 Apr 99	M-26	MOIRA L. STN ML-4A 2M	55	<0.01	<0.05	<0.01	<0.10
027	22 Apr 99	M-27	STOCO L. STN SL-1	71	<0.01	<0.05	<0.01	<0.10
028	22 Apr 99	M-28	STOCO L. STN SL-2	83	<0.01	<0.05	<0.01	<0.10
029	22 Apr 99	M-29	STOCO L. STN SL-3	36	0.01	<0.05	<0.01	<0.10
030	22 Apr 99	M-30	STOCO L. STN SL-4	88	<0.01	<0.05	<0.01	<0.10
031	22 Apr 99	M-31	STOCO L. STN SL-5	84	<0.01	<0.05	<0.01	<0.10
032	22 Apr 99	M-32	STOCO L. STN SL-1A 1M	31	<0.01	<0.05	<0.01	<0.10

Smp No.	Sampling Date	Station No.	Location	Moisture %	Ra-226 Bq/g	Ra-228 Bq/g	Th-228 Bq/g	U-238 Bq/g
033	22 Apr 99	M-33	STOCO L. STN SL-1A 2M	45	0.01	<0.05	0.02	<0.10
034	22 Apr 99	M-34	STOCO L. STN SL-51 1M	66	<0.01	<0.05	<0.01	<0.10
035	27 Apr 99	M-35	STOCO L. STN SL-5A 2M	80	<0.01	<0.05	<0.01	<0.10
036	22 Apr 99	M-36	STOCO L. STN SL-2A 1M	28	<0.01	<0.05	<0.01	<0.10
037	22 Apr 99	M-37	STOCO L. STN SL-2A 2M	28	0.01	<0.05	0.01	<0.10
038	22 Apr 99	M-39	STOCO L. STN SL-5B 2M	24	0.02	<0.05	<0.01	<0.10
039	22 Apr 99	M-40	STOCO L. STN SL-5C 1M	29	<0.01	<0.05	<0.01	<0.10
040	22 Apr 99	M-41	STOCO L. STN SL-5C 2M	30	<0.01	<0.05	<0.01	<0.10
041	29 Apr 99	M-42	MOIRA R. STN MR-10	43	<0.01	<0.05	<0.01	<0.10
042	23 Apr 99	M-43	ROUND L. STN RL-1	94	<0.01	<0.05	<0.01	<0.10
043	23 Apr 99	M-44	ROUND L. STN RL-2	93	<0.01	<0.05	<0.01	<0.10
044	23 Apr 99	M-45	ROUND L. STN RL-3	92	<0.01	<0.05	<0.01	<0.10
045	23 Apr 99	M-46	ROUND L. STN RL-1A 1M	60	<0.01	<0.05	<0.01	<0.10
046	23 Apr 99	M-47	ROUND L. STN RL-1A 2M	58	<0.01	<0.05	<0.01	<0.10
047	23 Apr 99	M-48	ROUND L. STN RL-2A 1M	45	<0.01	<0.05	0.01	<0.10
048	23 Apr 99	M-49	ROUND L. STN RL-2A 2M	82	<0.01	<0.05	<0.01	<0.10
049	26 Apr 99	M-50	CONSECON L. STN CL-1	61	<0.01	<0.05	<0.01	<0.10
050	26 Apr 99	M-51	CONSECON L. STN CL-2	71	<0.01	<0.05	<0.01	<0.10
051	26 Apr 99	M-52	CONSECON L. STN CL-3	45	<0.01	<0.05	<0.01	<0.10
052	26 Apr 99	M-53	CONSECON L. STN CL-1A 1M	57	<0.01	<0.05	<0.01	<0.10
053	27 Apr 99	M-54	CONSECON L. STN CL-1A 2M	52	<0.01	<0.05	<0.01	<0.10
054	26 Apr 99	M-55	CONSECON L. STN CL-3A 1M	36	<0.01	<0.05	<0.01	<0.10
055	26 Apr 99	M-56	CONSECON L. STN CL-3A 2M	31	<0.01	<0.05	<0.01	<0.10
056	03 May 99	M-57	BLACK R. STN BR-1	40	0.01	<0.05	<0.01	<0.10
057	03 May 99	M-58	SKOOTAMATTA R. STN SR-1	55	0.01	<0.05	<0.01	<0.10
058	27 Apr 99	M-59	MOIRA BELOW TUTTLE SHAFT	62	<0.01	<0.05	<0.01	<0.10
059	29 Apr 99	M-60	MOIRA R. AT CORBYVILLE	87	<0.01	<0.05	<0.01	<0.10
060	28 Apr 99	M-61	YOUNG'S CK. STN YC-1	87	0.05	<0.05	<0.01	<0.10
061	03 May 99	M-62	CONSECON L. DEEP BASIN	83	<0.01	<0.05	<0.01	<0.10
062	03 May 99	M-63	SALMON R. STN SR-R3	87	<0.01	<0.05	<0.01	<0.10
063	03 May 99	M-64	SALMON R. STN SR-R2	74	0.01	<0.05	<0.01	<0.10
064	03 May 99	M-65	SALMON R. STN SR-R1	61	0.01	<0.05	<0.01	<0.10

Samples were dried, ground and sealed for 30 days and then counted for 10,000 seconds by gamma spectrometry.
Data reported is "as is basis".

APPENDIX III

BENTHIC INVERTEBRATE ABUNDANCE DATA
AND
SEDIMENT TOXICITY TEST RESULTS

Appendix III.1 Benthic Invertebrate Abundance Data

Benthic Invertebrate Abundance Data for River Sites, Moira River System, Spring 1999

Waterbody	Black R.			Skootamatta R.			Salmon R.			Salmon R.			Salmon R.			Young's Ck.			Moira R.		
TAXON Site	BR-1	BR-1	BR-1	SKR-1	SKR-1	SKR-1	SR-1	SR-1	SR-1	SR-2	SR-2	SR-2	SR-3	SR-3	SR-3	YC-1	YC-1	YC-1	MR-1	MR-1	MR-1
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
COELENTERATA:																					
HYDRIDAE:																					
Hydra																					
PLATYHELMINTHES:																					
PLANARIIDAE:																					
"microturbellaria"																					
NEMERTEA:																					
Prostoma	8		4	8																	
NEMATODA:	16		12	16	64	32	32	8	96	16	20		8	4	4				32	56	60
ANNELIDA:																					
HIRUDINEA:																					
ERPOBDELLIDAE:																					
Mooreobdella fervida																					
GLOSSIPHONIIDAE:																					
Desserobdella phalera																					
Helobdella elongata				8																	
OLIGOCHAETA:																					
ENCHYTRAEIDAE:				48	64	8	136	24	80	16		4	24	8	4						
LUMBRICULIDAE:																					
Lumbriculus variegatus							8		8			4									
NAIDIDAE:																					
Arcteonais lomondi		16																			
Dero digitata	24	32	12				24	32		8			8	4			16				
Haemonais waldvogeli																					
Nais communis																					
Nais variabilis																					
Ophidonais serpentina								24	8												
Pristina aequiseta									8									8			
Slavinia appendiculata																					
Stylaria lacustris																					
SPARGANOPHILIDAE:																					
Sparganophilus eiseni				24	8																
TUBIFICIDAE:																					
Aulodrilus americanus																					
Aulodrilus limnobius																					
Aulodrilus pluriseta																				12	

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Black R.			Skootamatta R.			Salmon R.			Salmon R.			Salmon R.			Young's Ck.			Moira R.		
TAXON Site	BR-1	BR-1	BR-1	SKR-1	SKR-1	SKR-1	SR-1	SR-1	SR-1	SR-2	SR-2	SR-2	SR-3	SR-3	SR-3	YC-1	YC-1	YC-1	MR-1	MR-1	MR-1
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ilyodrilus templetoni					24	16		24	40	8	4	8							176	272	284
Limnodrilus spp.	16	24	24	32	16	56	392	240	264		32		32		4				52	124	72
Limnodrilus claparedianus									8	8										24	12
Limnodrilus hoffmeisteri					8	24	32	24	24		4		8						176	24	112
MOLLUSCA:																					
BIVALVIA:																					
SPHAERIIDAE:																					
Pisidium	16	48	4	88	128	72	8			32	24	16		4	8				16	32	112
Sphaerium striatinum										4			16								
GASTROPODA:																					
ANCYLIDAE:																					
Ferrissia															4						
HYDROBIIDAE:																					
Amnicola limosa	32	8	4			8	8				8									4	
Amnicola walkeri																					
Probythinella lacustris																					
LYMNAEIDAE: (juvenile)																					
Pseudosuccinea columella																					
PHYSIDAE:																					
Physella gyrina					8																
PLANORBIDAE:																					
Gyraulus deflectus																					
Gyraulus parvus			4	8				16		4	4			4							
Helisoma anceps																					
VALVATIDAE:																					
Valvata tricarinata		8				8															
VIVPARIDAE:																					
Campeloma decisum																					4
Viviparus georgianus																					
ACARINA:	8					8				4	4										
CRUSTACEA:																					
AMPHIPODA:																					
CRANGONYCTIDAE:																					
Crangonyx					8																
HYALELLIDAE:																					
Hyalella azteca	8			8						132	60	40	8		12						
ISOPODA:																					

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Black R.			Skootamatta R.			Salmon R.			Salmon R.			Salmon R.			Young's Ck.			Moira R.		
TAXON Site	BR-1	BR-1	BR-1	SKR-1	SKR-1	SKR-1	SR-1	SR-1	SR-1	SR-2	SR-2	SR-2	SR-3	SR-3	SR-3	YC-1	YC-1	YC-1	MR-1	MR-1	MR-1
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ASELLIDAE:																					
Caecidotea sp.										36	36	44	32	4							
OSTRACODA:	24	32	4							20											
INSECTA:																					
EPHEMEROPTERA:																					
BAETIDAE:																					
Acentrella										4											
Callibaetis																					
CAENIDAE:																					
Caenis	24	16	24			8						4						16			4
EPHEMERIDAE:																					
Ephemera simulans																					
Hexagenia limbata	8		12																		
HEPTAGENIIDAE:																					
Stenacron interpunctatum																					
Stenonema femoratum																					
ODONATA:																					
COENAGRIONIDAE:																					
Enallagma			4		8																
CORDULIIDAE:																					
Epicordulia princeps																					
GOMPHIDAE:																					
Gomphus sp.	24	8																			
HEMIPTERA:																					
BELOSTOMATIDAE:																					
Belostoma fluminea																					
MEGALOPTERA:																					
SIALIDAE:																					
Sialis																					
TRICHOPTERA:																					
DIPSEUDOPSIDAE:																					
Phylocentropus		8								4											
HELICOPSYCHIDAE:																					
Helicopsyche borealis																					
HYDROPSYCHIDAE:																					
Hydropsyche sparna																					
HYDROPTILIDAE:																					
Hydroptila																					
Oxyethira																					

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Black R.			Skootamatta R.			Salmon R.			Salmon R.			Salmon R.			Young's Ck.			Moira R.		
TAXON Site	BR-1	BR-1	BR-1	SKR-1	SKR-1	SKR-1	SR-1	SR-1	SR-1	SR-2	SR-2	SR-2	SR-3	SR-3	SR-3	YC-1	YC-1	YC-1	MR-1	MR-1	MR-1
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
LEPTOCERIDAE:																					
Ceraclea																					
Mystacides sepulchralis																					
Nectopsyche											4										
Oecetis	8																				
LIMNEPHILIDAE: (early instar)										4											
MOLANNIDAE:																					
Molanna																					
POLYCENTROPODIDAE:																					
Polycentropus																					
LEPIDOPTERA:																					
PYRALIDAE:																					
Acentria																					
COLEOPTERA:																					
ELMIDAE:																					
Dubiraphia	64	24	12		8					8	8	16								4	8
Dubiraphia vittata			8																		
Stenelmis																					
HALIPLIDAE:																					
Haliplus																					
HYDROPHILIDAE:																					
Berosus						8															
PSEPHENIDAE:																					
Ectopria nervosa																					
DIPTERA:																					
CERATOPOGONIDAE:	24	72	44	8	80	64	32	24	48	12	8	12		4			8		4	4	16
CHAOBORIDAE:																					
Chaoborus albatus																16	16	72			
Chaoborus punctipennis													24				40				
CHIRONOMIDAE:																					
CHIRONOMINAE:																					
Chironomus									16						4						
Cladopelma									16										4		
Cladotanytarsus		24																			
Cryptochironomus	8	8						8	16			4							8	16	12
Cryptotendipes																					
Dicrotendipes	32	32					16			32	12	4						16	4	4	4
Endochironomus																					
Glyptotendipes																					
Microtendipes			4			8		8	8						12						

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Black R.			Skootamatta R.			Salmon R.			Salmon R.			Salmon R.			Young's Ck.			Moira R.		
TAXON Site	BR-1	BR-1	BR-1	SKR-1	SKR-1	SKR-1	SR-1	SR-1	SR-1	SR-2	SR-2	SR-2	SR-3	SR-3	SR-3	YC-1	YC-1	YC-1	MR-1	MR-1	MR-1
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Nilothauma babiyi	8																				4
Pagastiella ostansa		8		40		8															
Parachironomus																					
Paracladopelma																					4
Paratanytarsus																			20	4	12
Paratendipes																					
Polypedilum	32	80	8				104	64	72	16	4			16					16	12	24
Pseudochironomus	16		4																	4	4
Stelechomyia perpulchra																					
Stempellinella			4	72	248	152													4		4
Stenochironomus																					4
Tanytarsus	232	240	76	48	56	16			8	88	20	32	8		4				76	44	136
Tribelos										28	4	8	8	8	4						8
Zavreliella							8			52	8	8	8	12							
ORTHOCLADIINAE:																					
Corynoneura																					
Cricotopus	8			24	8	16				4	4			4					4		
Epoicocladius																					
Nanocladius	8																			8	
Psectrocladius			8																		
Thienemanniella					8																
TANYPODINAE:																					
Ablabesmyia	40	16	4	40	64	40				60	8			8	8		8				4
Coelotanypus	24		12							56	16		16								
Conchapelopia			4																		
Labrundinia																					
Paramerina																					8
Procladius	80	64	24	48	32	56		8		4				4	4				8	4	36
TABANIDAE:																					
Chrysops																					
TIPULIDAE:																					
Oromosia (?)				8		16		8	8		4				8						
Pseudolimnophila																					
TOTAL TAXA	26	20	24	17	18	20	12	14	17	26	22	14	13	13	13	1	5	4	15	18	24
TOTAL NUMBERS	792	768	320	528	840	624	800	512	728	660	296	204	200	84	80	16	88	112	600	652	948

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Moira R.			Moira R.			Moira R.			Moira R.			Moira R.			Moira R.			Moira R.		
TAXON Site	MR-3	MR-3	MR-3	MR-5	MR-5	MR-5	MR-6	MR-6	MR-6	MR-7	MR-7	MR-7	MR-8	MR-8	MR-8	MR-9	MR-9	MR-9	MR-10	MR-10	MR-10
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
COELENTERATA:																					
HYDRIDAE:																					
Hydra										16											
PLATYHELMINTHES:																					
PLANARIIDAE:													4		8						
"microturbellaria"												4									
NEMERTEA:																					
Prostoma																					
NEMATODA:	8	8		16		8	8	8					8		4			32		16	
ANNELIDA:																					
HIRUDINEA:																					
ERPOBDELLIDAE:																					
Mooreobdella fervida																					
GLOSSIPHONIIDAE:																					
Deserobdella phalera																					
Helobdella elongata																					
OLIGOCHAETA:																					
ENCHYTRAEIDAE:	8									8	4										
LUMBRICULIDAE:																					
Lumbriculus variegatus			8																		
NAIDIDAE:																					
Arcteonais lomondi																			32		
Dero digitata			8			8															
Haemonais waldvogeli																					
Nais communis	8							8						8							
Nais variabilis		16																			
Ophidonais serpentina																				48	
Pristina aequiseta										8											
Slavinia appendiculata	8																				
Stylaria lacustris																					
SPARGANOPHILIDAE:																					
Sparganophilus eiseni																					
TUBIFICIDAE:																					
Aulodrilus americanus			16			4															
Aulodrilus limnobius				8																	
Aulodrilus pluriseta								32		24	2	16	60	80	68		32	32			16

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Moira R.			Moira R.			Moira R.			Moira R.			Moira R.			Moira R.			Moira R.		
TAXON Site	MR-3	MR-3	MR-3	MR-5	MR-5	MR-5	MR-6	MR-6	MR-6	MR-7	MR-7	MR-7	MR-8	MR-8	MR-8	MR-9	MR-9	MR-9	MR-10	MR-10	MR-10
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Ilyodrilus templetoni	8	8		8	12	16															
Limnodrilus spp.				136	80	36	168	256	176	64		20	84	96	84						16
Limnodrilus claparedianus																					
Limnodrilus hoffmeisteri										16	6										
MOLLUSCA:																					
BIVALVIA:																					
SPHAERIIDAE:																					
Pisidium	40	8		16	4	12	64	64	28	32	18	20	40	48	20	56	16	96		16	
Sphaerium striatinum		8	24																		
GASTROPODA:																					
ANCYLIDAE:																					
Ferrissia																					
HYDROBIIDAE:																					
Amnicola limosa				8	12	12			8	16	8		272	744	168					16	
Amnicola walkeri															12						
Probythinella lacustris											2										
LYMNAEIDAE: (juvenile)											6			8							
Pseudosuccinea columella																					
PHYSIDAE:																					
Physella gyrina										24	4	8	4								
PLANORBIDAE:																					
Gyraulus deflectus																					
Gyraulus parvus										64	12	20	20								
Helisoma anceps						8					2										
VALVATIDAE:																					
Valvata tricarinata					4	8				40	8		64	416	40						
VIVPARIDAE:																					
Campeloma decisum		8																			
Viviparus georgianus		8	16																		
ACARINA:					12	8		8					4		4	8					
CRUSTACEA:																					
AMPHIPODA:																					
CRANGONYCTIDAE:																					
Crangonyx																					
HYALELLIDAE:																					
Hyalella azteca	80		56			4				16	14	12		8						16	
ISOPODA:																					

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

	Waterbody	Moira R.			Moira R.			Moira R.			Moira R.			Moira R.			Moira R.			Moira R.		
TAXON	Site	MR-3	MR-3	MR-3	MR-5	MR-5	MR-5	MR-6	MR-6	MR-6	MR-7	MR-7	MR-7	MR-8	MR-8	MR-8	MR-9	MR-9	MR-9	MR-10	MR-10	MR-10
	Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
ASELLIDAE:																						
Caecidotea sp.																						
OSTRACODA:				8		8	16				24			12					16		16	
INSECTA:																						
EPHEMEROPTERA:																						
BAETIDAE:																						
Acentrella																						
Callibaetis																						
CAENIDAE:																						
Caenis					16	8	8	24	32	12	56	28	12	64	104	84	48		32			
EPHEMERIDAE:																						
Ephemera simulans		8																				
Hexagenia limbata			8			4		8	8		8			4		8	8					
HEPTAGENIIDAE:																						
Stenacron interpunctatum														8								
Stenonema femoratum																	8					
ODONATA:																						
COENAGRIONIDAE:																						
Enallagma							4							4		12						
CORDULIIDAE:																						
Epicordulia princeps						4																
GOMPHIDAE:																						
Gomphus sp.				8																		
HEMIPTERA:																						
BELOSTOMATIDAE:																						
Belostoma fluminea												2										
MEGALOPTERA:																						
SIALIDAE:																						
Sialis							4															
TRICHOPTERA:																						
DIPSEUDOPSIDAE:																						
Phylocentropus									16	4			4	4					16			
HELICOPSYCHIDAE:																						
Helicopsyche borealis																4						
HYDROPSYCHIDAE:																						
Hydropsyche sparna							4															
HYDROPTILIDAE:																						
Hydroptila											24	2	4									
Oxyethira							8				24											

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Moira R.			Moira R.			Moira R.			Moira R.			Moira R.			Moira R.			Moira R.		
TAXON Site	MR-3	MR-3	MR-3	MR-5	MR-5	MR-5	MR-6	MR-6	MR-6	MR-7	MR-7	MR-7	MR-8	MR-8	MR-8	MR-9	MR-9	MR-9	MR-10	MR-10	MR-10
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
LEPTOCERIDAE:																					
Ceraclea															8						
Mystacides sepulchralis		8								16	2			32							16
Nectopsyche																					
Oecetis				8	4					40		8	16		20						
LIMNEPHILIDAE: (early instar)																					
MOLANNIDAE:																					
Molanna											2										
POLYCENTROPODIDAE:																					
Polycentropus							8														
LEPIDOPTERA:																					
PYRALIDAE:																					
Acentria																					
COLEOPTERA:																					
ELMIDAE:																					
Dubiraphia	8		24		4	36	24	40	24	8	2		24	32	16			16		32	
Dubiraphia vittata																					
Stenelmis						8				8											
HALIPLIDAE:																					
Haliplus												4									
HYDROPHILIDAE:																					
Berosus														8							
PSEPHENIDAE:																					
Ectopria nervosa															4						
DIPTERA:																					
CERATOPOGONIDAE:	8	48	8	40	32	16	32	48	24	40	4	8	64	120	36	8	16			32	16
CHAOBORIDAE:																					
Chaoborus albatus																					
Chaoborus punctipennis																			16		16
CHIRONOMIDAE:																					
CHIRONOMINAE:																					
Chironomus																				16	
Cladopelma								16													16
Cladotanytarsus											2	12	8		8	32					
Cryptochironomus		8		16	16		16	8	12	16	2	16	8	24							
Cryptotendipes	88	72	40																		
Dicrotendipes			8	168	188	108	40	96	56	192	28	48	32	160	28	16	16	16	32	16	
Endochironomus																			16		
Glyptotendipes																				16	32
Microtendipes	8	8			4		8		4	16	2										

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Moira R.			Moira R.			Moira R.			Moira R.			Moira R.			Moira R.			Moira R.		
TAXON Site	MR-3	MR-3	MR-3	MR-5	MR-5	MR-5	MR-6	MR-6	MR-6	MR-7	MR-7	MR-7	MR-8	MR-8	MR-8	MR-9	MR-9	MR-9	MR-10	MR-10	MR-10
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Nilothauma babiyi												4									
Pagastiella ostansa					4					8			4								
Parachironomus														8							
Paracladopelma																					
Paratanytarsus							56	40	8	64	6	4									
Paratendipes																				32	
Polypedilum	8	16		16	28	16	32	16	8	16			8	24		16		32			
Pseudochironomus					8															16	
Stelechomyia perpulchra															4						
Stempellinella		8	40			16	8	8		16			4	16	24	32	16	32			
Stenochironomus																					
Tanytarsus	296	368	904	32	48	36	264	128	84	272	34	68	56	16	40	8		16	16		
Tribelos							48	72	28							24		32			
Zavreliella																				16	
ORTHOCLADIINAE:																					
Corynoneura														8	8						
Cricotopus						4	40	40	24	48	14	28	24	16	40						
Epoicocladius	8						16														
Nanocladius				8	12				8	64		12	8	32	8	8					
Psectrocladius						4	24	56	12		4	4			4						
Thienemanniella					4			8								8					
TANYPODINAE:																					
Ablabesmyia	8	8				8	8	8	8				4	8		8			32	32	
Coelotanypus						12				8							16				
Conchapelopia		8	24				16	48	12	72	6	8	32	72	40	8					
Labrundinia											2		12								
Paramerina				8	12	12															
Procladius	48	24		24	72	24	32	16	12	24			12	8		40	16	16	48	32	16
TABANIDAE:																					
Chrysops	8				4																
TIPULIDAE:																					
Oromosia (?)																					
Pseudolimnophila	8																				
TOTAL TAXA	19	19	15	16	25	30	22	25	20	35	29	23	32	25	28	17	7	13	7	16	8
TOTAL NUMBERS	664	648	1192	528	588	468	944	1080	552	1392	228	344	972	2096	804	336	128	384	192	368	144

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Moira R.			Moira R.			Moira R.			Moira R.		
TAXON Site	MR-12	MR-12	MR-12	MR-13	MR-13	MR-13	MR-14	MR-14	MR-14	MR-15	MR-15	MR-15
Replicate	A	B	C	A	B	C	A	B	C	A	B	C
COELENTERATA:												
HYDRIDAE:												
Hydra				48	80	16	12	4				
PLATYHELMINTHES:												
PLANARIIDAE:					16	16	4					
"microturbellaria"												
NEMERTEA:												
Prostoma										8		
NEMATODA:	32	16					16	4	8			
ANNELIDA:												
HIRUDINEA:												
ERPOBDELLIDAE:												
Mooreobdella fervida						16						
GLOSSIPHONIIDAE:												
Deserobdella phalera					8							
Helobdella elongata												
OLIGOCHAETA:												
ENCHYTRAEIDAE:				16	32		4					
LUMBRICULIDAE:												
Lumbriculus variegatus												
NAIDIDAE:												
Arcteonais lomondi												
Dero digitata				48	24	16	36	8	20			
Haemonais waldvogeli									4			
Nais communis												
Nais variabilis												
Ophidonais serpentina												
Pristina aequiseta				16	8							
Slavinia appendiculata				8	8	16	4					8
Stylaria lacustris							4	4	4			
SPARGANOPHILIDAE:												
Sparganophilus eiseni												
TUBIFICIDAE:												
Aulodrilus americanus												
Aulodrilus limnobius												
Aulodrilus pluriseta	64	48	64	8	16		28	48	12			

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Moira R.			Moira R.			Moira R.			Moira R.		
TAXON Site	MR-12	MR-12	MR-12	MR-13	MR-13	MR-13	MR-14	MR-14	MR-14	MR-15	MR-15	MR-15
Replicate	A	B	C	A	B	C	A	B	C	A	B	C
Ilyodrilus templetoni	16											
Limnodrilus spp.	80			8	16	32	12	40	76	24	24	40
Limnodrilus claparedianus	16						16		40			
Limnodrilus hoffmeisteri	48			8	8		4	4	56			
MOLLUSCA:												
BIVALVIA:												
SPHAERIIDAE:												
Pisidium	16	32	16	8	24		12	12	24		32	8
Sphaerium striatinum												
GASTROPODA:												
ANCYLIDAE:												
Ferrissia												
HYDROBIIDAE:												
Amnicola limosa		16		40	56	160	64	24	72	8	24	40
Amnicola walkeri												
Probythinella lacustris												
LYMNAEIDAE: (juvenile)												
Pseudosuccinea columella					16							
PHYSIDAE:												
Physella gyrina					24		4	8				
PLANORBIDAE:												
Gyraulus deflectus									4			
Gyraulus parvus				24	24		4		20	16	16	24
Helisoma anceps				8								
VALVATIDAE:												
Valvata tricarinata							4		12			8
VIVPARIDAE:												
Campeloma decisum												
Viviparus georgianus				8	24		16	16	28			
ACARINA:										8		8
CRUSTACEA:												
AMPHIPODA:												
CRANGONYCTIDAE:												
Crangonyx				16	8							
HYALELLIDAE:												
Hyalella azteca				32	120	144	20	12	4	112	8	216
ISOPODA:												

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Moira R.			Moira R.			Moira R.			Moira R.		
TAXON Site	MR-12	MR-12	MR-12	MR-13	MR-13	MR-13	MR-14	MR-14	MR-14	MR-15	MR-15	MR-15
Replicate	A	B	C	A	B	C	A	B	C	A	B	C
ASELLIDAE:												
Caecidotea sp.				8	32	16				24		16
OSTRACODA:								4				
INSECTA:												
EPHEMEROPTERA:												
BAETIDAE:												
Acentrella												
Callibaetis										8		
CAENIDAE:												
Caenis				16	8				8			
EPHEMERIDAE:												
Ephemera simulans												
Hexagenia limbata												
HEPTAGENIIDAE:												
Stenacron interpunctatum												
Stenonema femoratum												
ODONATA:												
COENAGRIONIDAE:												
Enallagma									4			
CORDULIIDAE:												
Epicordulia princeps												
GOMPHIDAE:												
Gomphus sp.												
HEMIPTERA:												
BELOSTOMATIDAE:												
Belostoma fluminea												
MEGALOPTERA:												
SIALIDAE:												
Sialis												
TRICHOPTERA:												
DIPSEUDOPSIDAE:												
Phylocentropus												
HELICOPSYCHIDAE:												
Helicopsyche borealis												
HYDROPSYCHIDAE:												
Hydropsyche sparna												
HYDROPTILIDAE:												
Hydroptila									4			
Oxyethira									4			8

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Moira R.			Moira R.			Moira R.			Moira R.		
TAXON Site	MR-12	MR-12	MR-12	MR-13	MR-13	MR-13	MR-14	MR-14	MR-14	MR-15	MR-15	MR-15
Replicate	A	B	C	A	B	C	A	B	C	A	B	C
LEPTOCERIDAE:												
Ceraclea												
Mystacides sepulchralis												
Nectopsyche												
Oecetis												
LIMNEPHILIDAE: (early instar)												
MOLANNIDAE:												
Molanna												
POLYCENTROPODIDAE:												
Polycentropus				16	8					8		8
LEPIDOPTERA:												
PYRALIDAE:												
Acentria					8							
COLEOPTERA:												
ELMIDAE:												
Dubiraphia				8								32
Dubiraphia vittata												
Stenelmis												
HALIPLIDAE:												
Haliplus												
HYDROPHILIDAE:												
Berosus												
PSEPHENIDAE:												
Ectopria nervosa												
DIPTERA:												
CERATOPOGONIDAE:	32		16	8	16			8	12		8	32
CHAOBORIDAE:												
Chaoborus albatus												
Chaoborus punctipennis	16											
CHIRONOMIDAE:												
CHIRONOMINAE:												
Chironomus	32	16										
Cladopelma												
Cladotanytarsus												
Cryptochironomus												
Cryptotendipes												
Dicrotendipes			16	48	16	16	8	12	32	88	16	56
Endochironomus												
Glyptotendipes	32	16		16								
Microtendipes												

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Moira R.			Moira R.			Moira R.			Moira R.		
TAXON Site	MR-12	MR-12	MR-12	MR-13	MR-13	MR-13	MR-14	MR-14	MR-14	MR-15	MR-15	MR-15
Replicate	A	B	C	A	B	C	A	B	C	A	B	C
Nilothauma babiyi												
Pagastiella ostansa												
Parachironomus												
Paracladopelma												
Paratanytarsus				8	16		4	48	40			
Paratendipes										8		40
Polypedilum				48	104		48	124	4	24		24
Pseudochironomus				56	32			4				
Stelechomyia perpulchra												
Stempellinella												
Stenochironomus												
Tanytarsus		16	16		24		40	8	16	24	24	152
Tribelos								4	4			
Zavreliella				16								8
ORTHOCLADIINAE:												
Corynoneura										8		8
Cricotopus					8		4	16	32	8		56
Epoicocladius												
Nanocladius												
Psectrocladius							12			16		
Thienemanniella												8
TANYPODINAE:												
Ablabesmyia				24	8	96		12	8	152		16
Coelotanypus	16											
Conchapelopia				16	40	64			4			
Labrundinia												24
Paramerina												
Procladius	48		16				4				56	16
TABANIDAE:												
Chrysops												
TIPULIDAE:												
Oromosia (?)												
Pseudolimnophila												
TOTAL TAXA	13	7	6	28	31	12	25	22	28	17	9	24
TOTAL NUMBERS	448	160	144	584	832	608	384	424	556	544	208	856

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999

Waterbody	Consecon L.			Consecon L.			Consecon L.			Consecon L.			Round L.			Round L.		
TAXON Site	CL-1	CL-1	CL-1	CL-2	CL-2	CL-2	CL-3	CL-3	CL-3	CL-D	CL-D	CL-D	RL-1	RL-1	RL-1	RL-2	RL-2	RL-2
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
PLATYHELMINTHES:																		
PLANARIIDAE:																		
NEMERTEA:																		
Prostoma																	22	38
NEMATODA:						32								8		2	2	8
ANNELIDA:																		
HIRUDINEA:																		
GLOSSIPHONIIDAE:																		
Helobdella stagnalis																		
OLIGOCHAETA:																		
ENCHYTRAEIDAE:																		
NAIDIDAE:																		
Arcteonais lomondi																14	22	38
Dero digitata																2	3	
Slavinia appendiculata																		
TUBIFICIDAE:																		
Aulodrilus americanus							2	10										
Aulodrilus limnobius																		
Aulodrilus pigueti																12	20	22
Aulodrilus pluriseta																		
Ilyodrilus templetoni										124	76	232				15	14	34
Limnodrilus spp.	16	4	4					2		24	24	76						
Limnodrilus claparedianus											4							
Limnodrilus hoffmeisteri	8	4								12	4	24						
Tubifex tubifex																		
MOLLUSCA:																		
BIVALVIA:																		
SPHAERIIDAE:																		
Pisidium	4		4													47	54	52
Sphaerium striatinum																		
UNIONIDAE: (juvenile)																		
Elliptio complanata																		
GASTROPODA:																		
HYDROBIIDAE:																		
Amnicola limosa								2										
VALVATIDAE:																		
Valvata sincera																2		
Valvata tricarinata													4					

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Consecon L.			Consecon L.			Consecon L.			Consecon L.			Round L.			Round L.		
TAXON Site	CL-1	CL-1	CL-1	CL-2	CL-2	CL-2	CL-3	CL-3	CL-3	CL-D	CL-D	CL-D	RL-1	RL-1	RL-1	RL-2	RL-2	RL-2
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
VIVPARIDAE:																		
Viviparus georgianus		8						4	6									
ACARINA:		4				12			2							7	5	16
CRUSTACEA:																		
AMPHIPODA:																		
CRANGONYCTIDAE:																		
Crangonyx							4											
HYALELLIDAE:																		
Hyalella azteca	20	28	32	2				6					12		4			
ISOPODA:																		
ASELLIDAE:																		
Caecidotea sp.	16	4																
OSTRACODA:						4												
INSECTA:																		
EPHEMEROPTERA:																		
CAENIDAE:																		
Caenis	8		4															
EPHEMERIDAE:																		
Hexagenia limbata	12	4		6		8	20	24	8									
ODONATA:																		
COENAGRIONIDAE:																		
Enallagma		4																
CORDULIIDAE:																		
Epicordulia princeps																		
MEGALOPTERA:																		
SIALIDAE:																		
Sialis								2										
TRICHOPTERA:																		
DIPSEUDOPSIDAE:																		
Phylocentropus									6									
HYDROPTILIDAE:																		
Oxyethira		4																
LEPTOCERIDAE:																		
Leptocerus americanus													4					
POLYCENTROPODIDAE:																		
Polycentropus		4																
DIPTERA:																		
CERATOPOGONIDAE:							2	6	8				4	8	4			
CHAOBORIDAE:																		

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Consecon L.			Consecon L.			Consecon L.			Consecon L.			Round L.			Round L.		
TAXON Site	CL-1	CL-1	CL-1	CL-2	CL-2	CL-2	CL-3	CL-3	CL-3	CL-D	CL-D	CL-D	RL-1	RL-1	RL-1	RL-2	RL-2	RL-2
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Chaoborus albatus													32	32		147	64	48
Chaoborus flavicans		4								16	24							
Chaoborus punctipennis		4	4	20	46	28	2			108	68	112	4			260	41	256
CHIRONOMIDAE:																		
CHIRONOMINAE:																		
Chironomus	24	64	8	2	4	20			4	116	64	148	44	8		66	45	64
Cladopelma																1		
Cladotanytarsus																		
Cryptochironomus	16																	
Dicrotendipes	32	4	12										20	80	20	1		
Einfeldia																		
Endochironomus																		
Glyptotendipes		24													8			
Microtendipes								2										
Parachironomus		136	4						2									
Paratanytarsus	40	92																
Phaenopsectra flavipes	4																	
Polypedilum	28	40					8	22	18									
Tanytarsus	64	36	60	4	10	4	40	54	38				8				1	
Tribelos	16			2					2									
Zavreliella																		
DIAMESINAE:																		
Monodiamesa							2	2										
ORTHOCLADIINAE:																		
Cricotopus	8	8																
Epoicocladius							2		2									
Heterotrissocladius		4	4						4									
Nanocladius													4					
Parakiefferiella															4			
Psectrocladius	8	104			2		2						4					
Synorthocladius																		
Thienemanniella																		
TANYPODINAE:																		
Ablabesmyia	20				2	4	6	12	12									
Coelotanypus		4		2		4	12	18	24									
Labrundinia								2										
Procladius	12	16	16	22	40	60	8	22	42	12	8	8		8	8	3		12
TOTAL TAXA	19	24	11	8	6	10	13	16	15	7	8	6	11	6	6	14	12	11
TOTAL NUMBERS	356	608	152	60	104	176	110	190	178	412	272	600	140	144	48	579	293	588

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Round L.			Moira River (Bend Bay)			Moira L.			Moira L.			Moira L.			Moira L.			Moira L.		
TAXON Site	RL-3	RL-3	RL-3	MR-11	MR-11	MR-11	ML-1	ML-1	ML-1	ML-2	ML-2	ML-2	ML-3	ML-3	ML-3	ML-4	ML-4	ML-4	ML-5	ML-5	ML-5
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
PLATYHELMINTHES:																					
PLANARIIDAE:	2	1				8															
NEMERTEA:																					
Prostoma		2														8	80	48	8		8
NEMATODA:	28	41	14		4		76	60	96	8	4	26									
ANNELIDA:																					
HIRUDINEA:																					
GLOSSIPHONIIDAE:																					
Helobdella stagnalis	10	2	3																		
OLIGOCHAETA:																					
ENCHYTRAEIDAE:																					
NAIDIDAE:																					
Arcteonais lomondi	14	12	3																		
Dero digitata	12	17	6	140	128	96	52	16	52	14	8	4									
Slavinia appendiculata																					
TUBIFICIDAE:																					
Aulodrilus americanus																					
Aulodrilus limnobius																				8	
Aulodrilus pigueti	2			12		16															
Aulodrilus pluriseta				8																	24
Ilyodrilus templetoni	2						24	10		12	12	20		32		56	48	24			
Limnodrilus spp.			3				36	24	96				24	8		8	16	16	16	8	8
Limnodrilus claparedianus																					
Limnodrilus hoffmeisteri																				16	8
Tubifex tubifex																					
MOLLUSCA:																					
BIVALVIA:																					
SPHAERIIDAE:																					
Pisidium	160	111	123	4	20		24	8	36	4	4	2							32	40	16
Sphaerium striatinum																					
UNIONIDAE: (juvenile)																					
Elliptio complanata																					
GASTROPODA:																					
HYDROBIIDAE:																					
Amnicola limosa	2	3	3						4												
VALVATIDAE:																					
Valvata sincera	10	10	5																		
Valvata tricarinata																					

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Round L.			Moira River (Bend Bay)			Moira L.			Moira L.			Moira L.			Moira L.			Moira L.		
TAXON Site	RL-3	RL-3	RL-3	MR-11	MR-11	MR-11	ML-1	ML-1	ML-1	ML-2	ML-2	ML-2	ML-3	ML-3	ML-3	ML-4	ML-4	ML-4	ML-5	ML-5	ML-5
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
VIVPARIDAE:																					
Viviparus georgianus																					
ACARINA:	6								8			2			8						
CRUSTACEA:																					
AMPHIPODA:																					
CRANGONYCTIDAE:																					
Crangonyx	2																				
HYALELLIDAE:																					
Hyalella azteca																					
ISOPODA:																					
ASELLIDAE:																					
Caecidotea sp.																					
OSTRACODA:				8	20	16		2			8										
INSECTA:																					
EPHEMEROPTERA:																					
CAENIDAE:																					
Caenis	2		1																		
EPHEMERIDAE:																					
Hexagenia limbata																					
ODONATA:																					
COENAGRIONIDAE:																					
Enallagma																					
CORDULIIDAE:																					
Epicordulia princeps																					
MEGALOPTERA:																					
SIALIDAE:																					
Sialis																					
TRICHOPTERA:																					
DIPSEUDOPSIDAE:																					
Phylocentropus																					
HYDROPTILIDAE:																					
Oxyethira																					
LEPTOCERIDAE:																					
Leptocerus americanus																					
POLYCENTROPODIDAE:																					
Polycentropus																					
DIPTERA:																					
CERATOPOGONIDAE:			1		8		16	16	20			2							8	8	16
CHAOBORIDAE:																					

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Round L.			Moira River (Bend Bay)			Moira L.			Moira L.			Moira L.			Moira L.			Moira L.		
TAXON Site	RL-3	RL-3	RL-3	MR-11	MR-11	MR-11	ML-1	ML-1	ML-1	ML-2	ML-2	ML-2	ML-3	ML-3	ML-3	ML-4	ML-4	ML-4	ML-5	ML-5	ML-5
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Chaoborus albatus	48	48	17	84	80	80	40	16	72	46	42	30	112	144	48	8	16				
Chaoborus flavicans											4	10									
Chaoborus punctipennis	52	56	12	72	40	72	20	34	40	28	34	36	64	56	64	24		8	16	24	16
CHIRONOMIDAE:																					
CHIRONOMINAE:																					
Chironomus	20	32	38					2			2				16					8	16
Cladopelma	2		1		16		16	8	24	4	2										8
Cladotanytarsus		1																			
Cryptochironomus			2					2	4			2									
Dicrotendipes	2	2		8		8														8	
Einfeldia																					
Endochironomus																					
Glyptotendipes																					
Microtendipes																					
Parachironomus																					
Paratanytarsus																					
Phaenopsectra flavipes																					
Polypedilum				4																	
Tanytarsus	6	2	3				4											16		24	
Tribelos			4																		
Zavreliella																					
DIAMESINAE:																					
Monodiamesa																					
ORTHOCLADIINAE:																					
Cricotopus											2	2									
Epoicocladius																					
Heterotrissocladius																					
Nanocladius																					
Parakiefferiella																					
Psectrocladius																					
Synorthocladius																					
Thienemanniella																					
TANYPODINAE:																					
Ablabesmyia				4						2									8		
Coelotanypus																					
Labrundinia																					
Procladius	16	25	16	44	48	32	20	10	28	22	30	38	32	56	72	24	24	80	16	56	32
TOTAL TAXA	20	16	18	11	9	8	11	13	12	9	12	12	4	5	5	6	5	6	7	10	10
TOTAL NUMBERS	398	365	255	388	364	328	328	208	480	140	152	174	232	296	208	128	184	192	104	200	152

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Stoco L.			Stoco L.			Stoco L.			Stoco L.			Stoco L.		
TAXON Site	SL-1	SL-1	SL-1	SL-2	SL-2	SL-2	SL-3	SL-3	SL-3	SL-4	SL-4	SL-4	SL-5	SL-5	SL-5
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
PLATYHELMINTHES:															
PLANARIIDAE:							4		2						
NEMERTEA:															
Prostoma															
NEMATODA:		8	8					4	1			1	1	1	
ANNELIDA:															
HIRUDINEA:															
GLOSSIPHONIIDAE:															
Helobdella stagnalis															
OLIGOCHAETA:															
ENCHYTRAEIDAE:									2						
NAIDIDAE:															
Arcteonais lomondi															
Dero digitata				2	6	5			14	5		10	35	34	13
Slavinia appendiculata													1		
TUBIFICIDAE:															
Aulodrilus americanus															
Aulodrilus limnobius															
Aulodrilus pigueti													15	16	9
Aulodrilus pluriseta		32	32												
Ilyodrilus templetoni															
Limnodrilus spp.		24	8	1	1	1	10	8	10	14	14	12	1		
Limnodrilus claparedianus															
Limnodrilus hoffmeisteri			8				8	6	4		6	1			
Tubifex tubifex	8	24	8	3	8	17	10	4	29	21	8	18	3	2	2
MOLLUSCA:															
BIVALVIA:															
SPHAERIIDAE:															
Pisidium			16	10	11	7	26	18	17	22	12	17	8	4	4
Sphaerium striatinum														1	
UNIONIDAE: (juvenile)									1						
Elliptio complanata								2							
GASTROPODA:															
HYDROBIIDAE:															
Amnicola limosa	8	40	8	5	5	4	84	34	34						
VALVATIDAE:															
Valvata sincera		8		5	3	4									
Valvata tricarinata				5	11	5	18	2	7						

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Stoco L.			Stoco L.			Stoco L.			Stoco L.			Stoco L.		
TAXON Site	SL-1	SL-1	SL-1	SL-2	SL-2	SL-2	SL-3	SL-3	SL-3	SL-4	SL-4	SL-4	SL-5	SL-5	SL-5
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
VIVPARIDAE:															
Viviparus georgianus															
ACARINA:					1	3							1		
CRUSTACEA:															
AMPHIPODA:															
CRANGONYCTIDAE:															
Crangonyx															
HYALELLIDAE:															
Hyalella azteca							4	4	2				1		
ISOPODA:															
ASELLIDAE:															
Caecidotea sp.															
OSTRACODA:										1					
INSECTA:															
EPHEMEROPTERA:															
CAENIDAE:															
Caenis															
EPHEMERIDAE:															
Hexagenia limbata															
ODONATA:															
COENAGRIONIDAE:															
Enallagma															
CORDULIIDAE:															
Epicordulia princeps							2								
MEGALOPTERA:															
SIALIDAE:															
Sialis				2	3	4	2		1						1
TRICHOPTERA:															
DIPSEUDOPSIDAE:															
Phylocentropus															
HYDROPTILIDAE:															
Oxyethira															
LEPTOCERIDAE:															
Leptocerus americanus	8	16	24			1									
POLYCENTROPODIDAE:															
Polycentropus															
DIPTERA:															
CERATOPOGONIDAE:						1	2			5	10	6	4	4	4
CHAOBORIDAE:															

Benthic Invertebrate Abundance Data for Lake Sites, Moira River System, Spring 1999 (continued)

Waterbody	Stoco L.			Stoco L.			Stoco L.			Stoco L.			Stoco L.		
TAXON Site	SL-1	SL-1	SL-1	SL-2	SL-2	SL-2	SL-3	SL-3	SL-3	SL-4	SL-4	SL-4	SL-5	SL-5	SL-5
Replicate	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Chaoborus albatus				5	5	2		2		25	51	54	43	29	31
Chaoborus flavicans															
Chaoborus punctipennis			24	3	2	7	4	2		57	70	50	29	30	24
CHIRONOMIDAE:															
CHIRONOMINAE:															
Chironomus		24				2	2		1	1	1	1			
Cladopelma					1		4		3	2	1			1	1
Cladotanytarsus															
Cryptochironomus		8					2	2	2						
Dicrotendipes							14	6	3	2		1	1		
Einfeldia					5	4	2								
Endochironomus											1				
Glyptotendipes															
Microtendipes				1											
Parachironomus															
Paratanytarsus							2		1						
Phaenopsectra flavipes															
Polypedilum	8		8				22	16	16						
Tanytarsus			8	4	2	6	4		2			1	2		
Tribelos		8					12		4						
Zavreliella	8														
DIAMESINAE:															
Monodiamesa															
ORTHOCLADIINAE:															
Cricotopus												1			
Epoicocladius															
Heterotrissocladius															
Nanocladius															
Parakiefferiella															
Psectrocladius															
Synorthocladius		16													
Thienemanniella														1	
TANYPODINAE:															
Ablabesmyia				1				2	1						
Coelotanypus															
Labrundinia															
Procladius	56	48	24	27	84	74	34	14	11	67	35	70	42	31	28
TOTAL TAXA	6	12	12	14	15	17	22	16	23	12	11	14	15	12	10
TOTAL NUMBERS	96	256	176	74	148	147	272	126	168	222	209	243	187	154	117

Appendix III.2 Results of Toxicity Tests Using *Chironomus riparius* and *Hyalella azteca*

ESG INTERNATIONAL

29 July 1999

Mr. Jim Kroetch
Golder Associates
2180 Meadowvale Blvd.
Mississauga, ON
L5N 5S3

Dear Mr. Kroetch,

Re: Toxicity Analysis of Sediment Samples

Please find the enclosed reports for sediment toxicity testing conducted on samples received May 10, 1999. The reports include both the results and data regarding the test conditions.

As reported previously, tests conducted using *Chironomus riparius* and initiated on June 8, 1999 were invalid because control mortality exceeded the maximum allowed under Environment Canada Protocols. As required under internal quality control practices, an investigation of the test system was initiated to determine if the cause of the control mortality could be identified. Our investigation included a review of internal procedures related to the performance of the test system during the period. They included but were not limited to light intensity and photoperiod maintenance, temperature, feeding regime, aeration rates, preparation of test chambers, routine chemistry of control water, organism history and handling. No abnormalities were identified with respect to the operation of the test system. There was no unusual mortality observed in reference toxicant testing conducted within a week of the test. It must be noted however, that reference toxicant assays for sediment tests differ slightly from the actual sediment test in that they are shorter term and test performance of the organism is in a "water only" environment.

Remedial action included immediately informing the test sponsor, Golder Associates. Approval was given for a retest of the samples. The retest was initiated on June 23, 1999. Test reports for these sediments indicate that storage time exceeded 6 weeks.

ESG INTERNATIONAL Mailing Address: 361 Southgate Drive Guelph, Ontario Canada N1G 3M5 Voice (519) 836-6050 Fax (519) 763-4419 Internet *www.esg.net*
Shipping Address: 11B Nicholas Beaver Road RR#3 Guelph, Ontario Canada N1H 6H9

As stated in our original proposal, leftover sediments are to be returned to the client for disposal. We await your shipping instructions.

Sincerely,
ESG INTERNATIONAL INC.

Jim Reid
Laboratory Supervisor

Enclosures

JR/jr

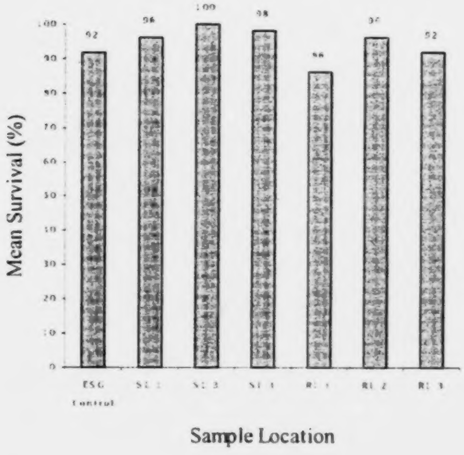
Sample Identification

Company	Golder Associates	Date Tested	05/21/99
Location	Missassauga, ON	Date Test Completed	06/04/99
Sample Method	Grab	Shipped By	R. Yaagumagi
Sampled By	R. Yaagumagi	Lab Storage (°C)	6.0
Date and Time Received	05/10/99@ 11 00	Sample Volume	10 L

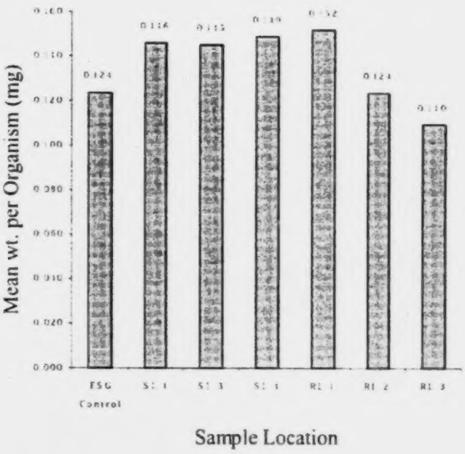
Substance	Date Collected	ESG Sample Number	Description
Control			-fine black sediment, no strong odour.
Stoco Lk. SL-1	04/22/99	03990548	-fine dark olive-brown sediment, some organic debris, slight odour.
Stoco Lk. SL-3	04/22/99	03990562	-fine, dark olive-brown sediment, lots of organic debris, slight odour.
Stoco Lk. SL-4	04/22/99	03990563	-fine, dark olive-brown sediment, slight odour.
Round Lk. RL-1	04/23/99	03990558	-fine, dark olive-brown sediment, some plant material, slight odour.
Round Lk. RL-2	04/23/99	03990559	-fine dark brown-green sediment, no strong odour.
Round Lk. RL-3	04/23/99	03990560	-fine, dark brown-black sediment, no strong odour.

Results

***Hyalella azteca* Survival**



***Hyalella azteca* Growth**



Station	Replicate	% Surviving Organisms	Overall Average Survival %	SD	CV	Mean Dry wt/organism (mg)	Overall Average wt/Organism (mg)	S.D.	CV
control	A	100	92	4.472	4.861	0.143	0.124	0.012	9.555
	B	90				0.118			
	C	90				0.127			
	D	90				0.118			
	E	90				0.113			
SL-1 03990548	A	100	96	8.944	9.317	0.148	0.146	0.022	14.714
	B	100				0.123			
	C	100				0.131			
	D	80				0.179			
	E	100				0.151			
SL-3 03990562	A	100	100	0	0	0.129	0.145	0.014	9.536
	B	100				0.156			
	C	100				0.159			
	D	100				0.132			
	E	100				0.150			
SL-4 03990563	A	100	98	4.472	4.563	0.130	0.149	0.015	10.061
	B	90				0.147			
	C	100				0.172			
	D	100				0.151			
	E	100				0.147			
RL-1 03990558	A	80	86	8.944	10.400	0.133	0.152	0.023	15.225
	B	80				0.141			
	C	90				0.133			
	D	80				0.184			
	E	100				0.169			
RL-2 03990559	A	90	96	5.477	5.705	0.124	0.124	0.011	8.739
	B	100				0.108			
	C	90				0.121			
	D	100				0.136			
	E	100				0.132			
RL-3 03990560	A	90	92	4.472	4.861	0.108	0.110	0.009	7.716
	B	90				0.107			
	C	100				0.115			
	D	90				0.122			
	E	90				0.100			

Technician : ____________________

Toxicity Test Chemistry Parameters

Sediment		Day						
		0	3	5	7	10	12	14
Control	Temp. (°C)	24.0	24.0	23.5	23.0	23.0	23.0	23.0
	D.O. (mg/L)	8.0	8.0	6.9	7.9	8.0	8.2	8.0
	pH	8.4						8.5
	Conductivity	546						676
	Ammonia (mg/L)	2.6						0.25
	Hardness (mg/L)	270						320
Stoco Lk.-SL-1	Temp. (°C)	24.0	24.0	23.5	23.0	23.0	23.0	23.0
03990548	D.O. (mg/L)	7.7	7.7	6.7	8.2	7.5	8.2	8.4
	pH	8.0						8.2
	Conductivity	431						356
	Ammonia (mg/L)	1.25						0.25
	Hardness (mg/L)	220						160
Stoco Lk.-SL-3	Temp. (°C)	24.0	24.0	23.5	23.0	23.0	23.0	23.0
03990562	D.O. (mg/L)	8.1	8.2	7.2	8.2	8.0	8.1	8.4
	pH	8.3						8.3
	Conductivity	504						468
	Ammonia (mg/L)	2.75						0.25
	Hardness (mg/L)	270						200
Stoco Lk.-SL-4	Temp. (°C)	24.0	24.0	23.5	23.0	23.0	23.0	23.0
03990563	D.O. (mg/L)	7.8	8.1	6.8	8.2	7.7	8.2	8.3
	pH	8.1						7.9
	Conductivity	436						298
	Ammonia (mg/L)	1.35						0.3
	Hardness (mg/L)	210						140
Round Lk- RL-1	Temp. (°C)	24.0	24.0	23.5	23.0	23.0	23.0	23.0
03990558	D.O. (mg/L)	7.8	8.2	7.9	8.2	8.2	8.4	8.6
	pH	8.2						8.2
	Conductivity	517						410
	Ammonia (mg/L)	1.25						0.2
	Hardness (mg/L)	240						170
Round Lk. - RL-2	Temp. (°C)	24.0	24.0	23.5	23.0	23.0	23.0	23.0
03990559	D.O. (mg/L)	7.9	8.0	7.3	8.2	8.1	8.3	8.4
	pH	8.1						8.1
	Conductivity	397						356
	Ammonia (mg/L)	0.7						0.1
	Hardness (mg/L)	200						160
Round Lk. - RL-3	Temp. (°C)	24.0	24.0	23.5	23.0	23.0	23.0	23.0
03990560	D.O. (mg/L)	7.8	8.0	6.5	8.4	8.2	8.3	8.4
	pH	7.9						7.8
	Conductivity	406						390
	Ammonia (mg/L)	0.85						0.1
	Hardness (mg/L)	210						170

Date:____________________

Approved by:__________________________
Jim Reid, Laboratory Supervisor

Test Conditions

Test Organism	*Hyalella azteca*	Sediment Volume (mL)	100
Source	AIB, Burlington, ON	Control/Dilution Water	undiluted well water[a]
Life Stage at Start	2 - 9 day old	Overlying Water Volume (mL)	175
Test Type	Static	Test Aeration Rate	2-3 bubbles/second
No. Discrete Samples/Treatment	1	Photoperiod (h) light/dark	16/8
Number of Replicates	5	Temperature	23 ± 1 °C
Number of Organisms per Replicate	10	Feeding Rate	2.7 mg dry solids in 1.5 mL suspension / replicate
Number of Organisms per Treatment	50	Feeding Frequency	Daily
Sediment Depth	3.5 cm	Test Duration	14 days

[a] Control/Dilution Water: No chemicals added.

Test Protocol:	Biological Test Method: Test for Survival and Growth in Sediment Using the Freshwater amphipod *Hyalella azteca*). Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/33.
Test Organisms:	No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test. Previous 48 h culture mortality <1%.
Control Sediment:	Obtained from Long Point, Ontario.
Test Conditions:	There were no unusual conditions or deviations from the test protocol.

Reference Toxicant Data

Substance	Copper (from copper sulphate)
Test Date	06 / 04 / 99
LC50 Survival (95% confidence limits)	176.8 μg/L (125 - 500)
Test Duration	96 hours
Historical Mean LC50	206.9 μg/L
Warning Limits (± 2 SD)	60.5 - 351.8
Statistical Method	Linear Interpolation (Toxstat 3.5)[a]

References

[a] West, Inc. and D. Gulley. 1996. Toxstat Release 3.5. Western Ecosystems Technology. Cheyenne, WY, U.S.A

SEDIMENT TEST REPORT

Chironomus riparius Survival and Growth

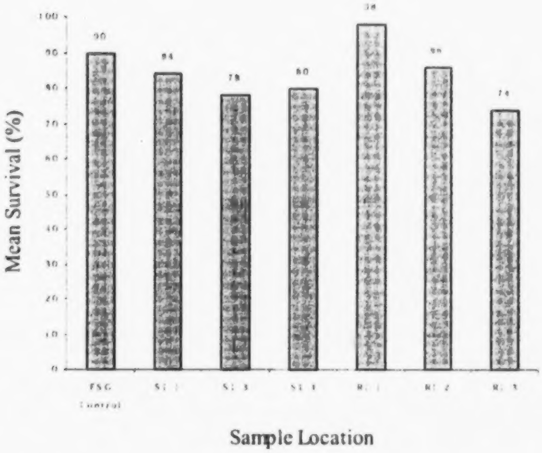
Sample Identification

Company	: Golder Associates		Date Tested	:	06/02/ 99
Location	: Missassauga, ON		Date Test Completed	:	06/12/99
Sample Method	: Grab		Shipped By	:	R. Yaagumagi
Sampled By	: R. Yaagumagi		Lab Storage (°C)	:	6.0
Date and Time Received	: 05/10/99 @ 11 00		Sample Volume	:	10 L

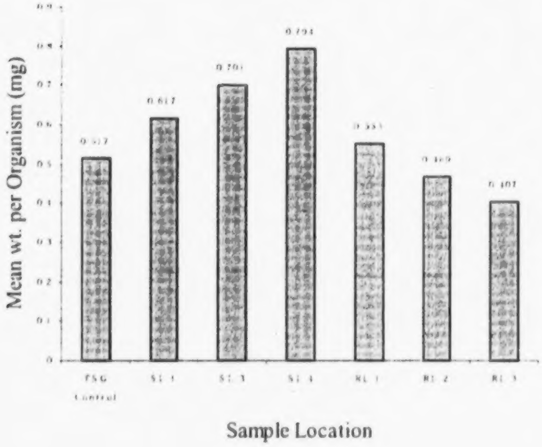
Substance	Date Collected	ESG Sample Number	Description
Control			-fine black sediment, no strong odour.
Stoco Lk. SL-1	04/22/99	03990548	-fine dark olive-brown sediment, some organic debris, slight odour.
Stoco Lk. SL-3	04/22/99	03990562	-fine, dark olive-brown sediment, lots of organic debris, slight odour.
Stoco Lk. SL-4	04/22/99	03990563	-fine, dark olive-brown sediment, slight odour.
Round Lk. RL-1	04/23/99	03990558	-fine, dark olive-brown sediment, some plant material, slight odour.
Round Lk. RL-2	04/23/99	03990559	-fine dark brown-green sediment, no strong odour.
Round Lk. RL-3	04/23/99	03990560	-fine, dark brown-black sediment, no strong odour.

Results

Chironomus riparius **Survival**



Chironomus riparius **Growth**



SEDIMENT TEST REPORT

Chironomus riparius Survival and Growth

Station	Replicate	% Surviving Organisms	Overall Average Survival (%)	SD	CV	Mean Dry wt/Organism (mg)	Overall Average wt/Organism (mg)	SD	CV
control	A	100	90	12.247	13.608	0.623	0.517	0.296	57.338
	B	90				0.489			
	C	70				0.547			
	D	90				0.871			
	E	100				0.055			
SL-1 03990548	A	100	84	18.166	21.626	0.523	0.617	0.127	20.589
	B	60				0.450			
	C	70				0.646			
	D	100				0.719			
	E	90				0.746			
SL-3 3990562	A	60	78	21.679	27.794	0.753	0.701	0.205	29.279
	B	50				0.640			
	C	100				0.573			
	D	90				1.030			
	E	90				0.508			
SL-4 3990563	A	70	80	14.142	17.678	0.859	0.794	0.108	13.640
	B	90				0.727			
	C	90				0.636			
	D	90				0.881			
	E	60				0.868			
RL-1 03990558	A	100	98	4.472	4.563	0.611	0.553	0.091	16.478
	B	100				0.403			
	C	100				0.529			
	D	100				0.618			
	E	90				0.603			
RL-2 03990559	A	100	86	16.733	19.457	0.548	0.469	0.085	18.144
	B	90				0.512			
	C	60				0.527			
	D	80				0.352			
	E	100				0.406			
RL-3 03990560	A	90	74	20.736	28.022	0.439	0.407	0.127	31.145
	B	70				0.586			
	C	80				0.289			
	D	40				0.280			
	E	90				0.442			

Technician : ____________________

Toxicity Test Chemistry Parameters

Sediment		Day					
		0	2	5	7	9	10
Control	Temp. (°C)	23.0	22.5	22.5	22.5	23.0	23.0
	D.O. (mg/L)	8.3	8.5	4.8	8.4	8.5	8.3
	pH	8.3					8.1
	Conductivity	451					430
	Ammonia (mg/L)	4.1					0.55
	Hardness (mg/L)	260					210
Stoco Lk.-SL-1 03990548	Temp. (°C)	23.0	22.5	22.5	22.5	23.0	23.0
	D.O. (mg/L)	8.3	8.3	8.5	8.3	7.9	6.9
	pH	8.3					7.6
	Conductivity	417					376
	Ammonia (mg/L)	0.9					0.4
	Hardness (mg/L)	270					170
Stoco Lk.-SL-3 03990562	Temp (°C)	23.0	22.5	22.5	22.5	23.0	23.0
	D.O. (mg/L)	8.3	8.0	7.5	8.0	8.3	7.9
	pH	8.4					8.1
	Conductivity	533					438
	Ammonia (mg/L)	2.25					0.3
	Hardness (mg/L)	250					220
Stoco Lk.-SL-4 03990563	Temp (°C)	23.0	22.5	22.5	22.5	23.0	23.0
	D.O. (mg/L)	8.3	8.0	8.4	7.5	8.6	8.1
	pH	8.0					7.6
	Conductivity	404					363
	Ammonia (mg/L)	0.35					0.35
	Hardness (mg/L)	220					160
Round Lk- RL-1 03990558	Temp (°C)	23.0	22.5	22.5	22.5	23.0	23.0
	D.O. (mg/L)	8.2	8.2	8.4	7.9	7.5	7.6
	pH	8.3					8.0
	Conductivity	405					411
	Ammonia (mg/L)	2.1					2.9
	Hardness (mg/L)	200					180
Round Lk. - RL-2 03990559	Temp. (°C)	23.0	22.5	22.5	22.5	23.0	23.0
	D.O. (mg/L)	8.6	8.0	8.4	8.3	8.6	8.3
	pH	8.3					8.0
	Conductivity	378					363
	Ammonia (mg/L)	0.35					0.45
	Hardness (mg/L)	230					180
Round Lk. - RL-3 03990560	Temp. (°C)	23.0	22.5	22.5	22.5	23.0	23.0
	D.O. (mg/L)	8.4	8.4	8.5	8.3	8.5	8.3
	pH	8.2					8.0
	Conductivity	407					418
	Ammonia (mg/L)	0.5					1.95
	Hardness (mg/L)	210					180

Date:____________________

Approved by:__________________________
Jim Reid, Laboratory Supervisor

Test Conditions

Test Organism	*Chironomus riparius*	Sediment Volume (mL)	100
Source	University of Waterloo	Control/Dilution Water	undiluted well water[a]
Life Stage at Start	1st instar (<48h post hatch)	Overlying Water Volume (mL)	175
Test Type	Static	Test Aeration Rate	2-3 bubbles/second
No. Discrete Samples/Site	1	Photoperiod (h) light/dark	16/8
Number of Replicates	5	Temperature	23 ± 1 °C
Number of Organisms per Replicate	10	Feeding Rate	6 mg dry solids in 1.5 mL suspension / replicate
Number of Organisms per Treatment	50	Feeding Frequency	Daily
Sediment Depth	approx. 3.5 cm	Test Duration	10 days

a Control/Dilution Water: No chemicals added.

Test Protocol: Biological Test Method: Test for Survival and Growth in Sediment Using the Larvae of Freshwater Midges (*Chironomus tentans* or *Chironomus riparius*). Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/32.

Test Organisms: No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.

Control Sediment: Obtained from Long Point, Ontario

Test Conditions: There were no unusual conditions or deviations from the test protocol.

Reference Toxicant Data

Substance	Copper (from copper sulphate)
Test Date	06 /04/ 99
LC50 Survival (95% confidence limits)	176.8 μg/L (125 - 250)
Test Duration	96 hours
Historical Mean LC50	198.7 μg/L
Warning Limits (± 2 SD)	0 - 552.2
Statistical Method	Linear Interpolation (Toxstat 3.5)[a]

References

[a] West, Inc. and D. Gulley. 1996. Toxstat Release 3.5. Western Ecosystems Technology. Cheyenne, WY, U.S.A.

SEDIMENT TEST REPORT

Hyalella azteca Survival and Growth

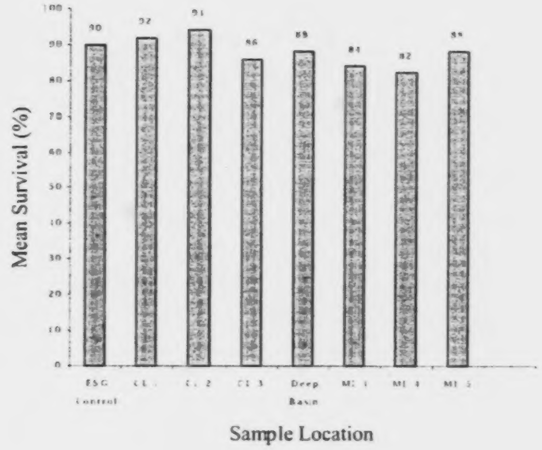
Sample Identification

Company	:	Golder Associates	Date Tested	:	05/26/99
Location	:	Missassauga, ON	Date Test Completed	:	06/09/99
Sample Method	:	Grab	Shipped By	:	R. Yaagumagi
Sampled By	:	R. Yaagumagi	Lab Storage (°C)	:	6.0
Date and Time Received	:	05/10/99 @ 11 00	Sample Volume	:	10 L

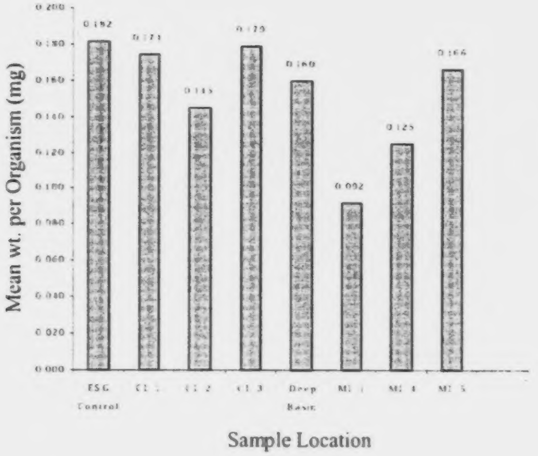
Substance	Date Collected	ESG Sample Number	Description
Control			-fine black sediment, no strong odour.
Consecon Lk. CL-1	04/26/99	03990547	-coarse, greenish-grey sediment, large amounts of organic material (mollusc shells), slight odour.
Consecon Lk. CL-2	04/26/99	03990546	-very fine, dark olive-green sediment, slight odour.
Consecon Lk. CL-3	04/26/99	03990544	-fine-coarse, dark olive-green sediment, large amounts of organic material (molluscs shells, wood), some odour.
Consecon Lk. CL-Deep Basin	05/03/99	03990549	-fine dark green-grey sediment, slight odour.
Moira Lk. ML-1	04/22/99	03990551	-very fine black sediment, slight odour.
Moira Lk. ML-4	04/27/99	03990557	-fine, black sediment, slight odour.
Moira Lk. ML-5	04/27/99	03990556	-coarse, black sediment, large amounts of organic material (mollusc shells), slight odour.

Results

***Hyalella azteca* Survival**



***Hyalella azteca* Growth**



SEDIMENT TEST REPORT

Hyalella azteca Survival and Growth

Station	Replicate	% Surviving Organisms	Overall Survival %	SD	CV	Mean dry wt. per Organism (mg)	Overall Average wt/Organism (mg)	S.D.	CV
control	A	100	90	10.000	11.111	0.179	0.182	0.022	12.266
	B	100				0.155			
	C	80				0.200			
	D	80				0.168			
	E	90				0.209			
CL-1 03990547	A	100	92	13.038	14.172	0.177	0.174	0.023	13.014
	B	90				0.144			
	C	100				0.194			
	D	100				0.157			
	E	70				0.196			
CL-2 03990654	A	100	94	8.944	9.515	0.165	0.145	0.019	13.126
	B	100				0.140			
	C	80				0.115			
	D	100				0.147			
	E	90				0.156			
CL-3 03990544	A	100	86	19.494	22.667	0.155	0.179	0.034	19.244
	B	60				0.152			
	C	70				0.174			
	D	100				0.237			
	E	100				0.175			
CL-Deep Basin 03990549	A	100	88	10.954	12.448	0.184	0.160	0.027	16.661
	B	80				0.160			
	C	80				0.188			
	D	100				0.123			
	E	80				0.147			
ML-1 03990551	A	90	84	8.9442719	10.647943	0.076	0.092	0.014	15.442
	B	90				0.109			
	C	90				0.099			
	D	70				0.079			
	E	80				0.096			
ML-4 03990557	A	90	82	4.472	5.454	0.129	0.125	0.008	6.582
	B	80				0.129			
	C	80				0.129			
	D	80				0.110			
	E	80				0.126			
ML-5 03990556	A	80	88	10.954	12.448	0.199	0.166	0.027	16.142
	B	80				0.136			
	C	100				0.158			
	D	80				0.190			
	E	100				0.149			

Technician : ____________________

Toxicity Test Chemistry Parameters

Sediment		Day						
		0	2	5	7	9	12	14
Control	Temp. (°C)	23.0	23.0	23.0	23.0	22.5	22.5	23.0
	D.O. (mg/L)	8.4	8.3	8.4	8.3	8.2	8.3	8.2
	pH	8.4						8.4
	Conductivity	541						658
	Ammonia (mg/L)	0						0.05
	Hardness (mg/L)	270						340
Consecon Lk.-CL-1 03990547	Temp. (°C)	22.0	23.0	23.0	23.0	22.5	22.5	23.0
	D.O. (mg/L)	8.4	8.4	8.4	8.3	8.7	8.6	8.4
	pH	8.5						8.4
	Conductivity	510						478
	Ammonia (mg/L)	0						0.05
	Hardness (mg/L)	190						240
Consecon Lk.-CL-2 03990546	Temp. (°C)	22.0	23.0	23.0	23.0	22.0	22.5	23.0
	D.O. (mg/L)	8.3	8.5	8.3	8.5	8.5	8.5	7.3
	pH	8.4						8.4
	Conductivity	504						615
	Ammonia (mg/L)	1.15						0.05
	Hardness (mg/L)	260						260
Consecon Lk.-CL-3 03990544	Temp. (°C)	23.0	23.0	23.0	23.0	22.0	22.5	23.0
	D.O. (mg/L)	8.4	8.5	8.6	8.5	8.3	8.5	7.9
	pH	8.5						8.4
	Conductivity	524						561
	Ammonia (mg/L)	0						0.1
	Hardness (mg/L)	320						260
Consecon Lk. CL-Deep Basin 03990549	Temp. (°C)	23.0	23.0	23.0	23.0	22.5	22.5	23.0
	D.O. (mg/L)	8.4	8.4	8.0	8.4	8.6	8.4	7.5
	pH	8.5						8.5
	Conductivity	533						674
	Ammonia (mg/L)	0						0.1
	Hardness (mg/L)	280						360
Moira Lk. - ML-1 03990551	Temp. (°C)	22.0	23.0	23.0	23.0	22.5	22.5	23.0
	D.O. (mg/L)	8.6	8.3	8.3	8.1	8.3	8.3	8.1
	pH	8.4						8.3
	Conductivity	495						506
	Ammonia (mg/L)	0						0.05
	Hardness (mg/L)	270						260
Moira Lk. - ML-4 03990557	Temp. (°C)	23.0	23.0	23.0	23.0	22.5	22.5	23.0
	D.O. (mg/L)	8.3	8.5	8.5	8.3	8.3	8.5	8.2
	pH	8.4						8.1
	Conductivity	516						544
	Ammonia (mg/L)	0						0
	Hardness (mg/L)	370						280
Moira Lk. - ML-5 03990556	Temp. (°C)	22.0	23.0	23.0	23.0	22.5	22.5	23.0
	D.O. (mg/L)	8.5	8.4	8.4	8.4	8.5	8.5	8.1
	pH	8.4						8.2
	Conductivity	496						543
	Ammonia (mg/L)	0.0						0.1
	Hardness (mg/L)	260						280

Date:____________________

Approved by:________________________
Jim Reid, Laboratory Supervisor

Test Conditions

Test Organism	:	*Hyalella azteca*	Sediment Volume (mL)	:	100
Source	:	AIB, Burlington, ON	Control/Dilution Water	:	undiluted well water[a]
Life Stage at Start	:	2 - 9 day old	Overlying Water Volume (mL)	:	175
Test Type	:	Static	Test Aeration Rate	:	2-3 bubbles/second
No. Discrete Samples/Treatment	:	1	Photoperiod (h) light/dark	:	16/8
Number of Replicates	:	5	Temperature	:	23 ± 1 °C
Number of Organisms per Replicate	:	10	Feeding Rate	:	2.7 mg dry solids in 1.5 mL suspension / replicate
Number of Organisms per Treatment	:	50	Feeding Frequency	:	Daily
Sediment Depth	:	3.5 cm	Test Duration	:	14 days

a Control/Dilution Water: No chemicals added.

Test Protocol:	Biological Test Method: Test for Survival and Growth in Sediment Using the Larvae of Freshwater Amphipod *Hyalella azteca*. Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/33.
Test Organisms:	No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test. Previous 48 h culture mortality <1%.
Control Sediment:	Obtained from Long Point, Ontario.
Test Conditions:	There were no unusual conditions or deviations from the test protocol.

Reference Toxicant Data

Substance	:	Copper (from copper sulphate)
Test Date	:	06 / 04 / 99
LC50 Survival (95% confidence limits)	:	178.6 μg/L (125 - 500)
Test Duration	:	96 hours
Historical Mean LC50	:	206.9 μg/L
Warning Limits (± 2 SD)	:	60.5 - 351.8
Statistical Method	:	Linear Interpolation (Toxstat 3.5)[a]

References

[a] West, Inc. and D. Gulley. 1996. Toxstat Release 3.5. Western Ecosystems Technology. Cheyenne, WY, U.S.A.

SEDIMENT TEST REPORT

Chironomus riparius Survival and Growth

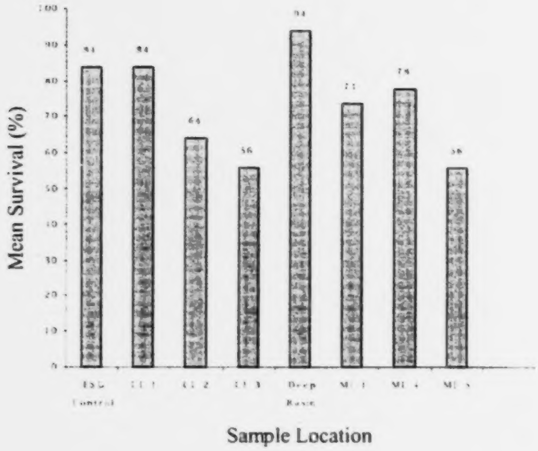
Sample Identification

Company	: Golder Associates		Date Tested	:	05/20/ 99
Location	: Missassauga, ON		Date Test Completed	:	05/30/99
Sample Method	: Grab		Shipped By	:	R. Yaagumagi
Sampled By	: R. Yaagumagi		Lab Storage (°C)	:	6.0
Date and Time Received	: 05/10/99 @ 11 00		Sample Volume	:	10 L

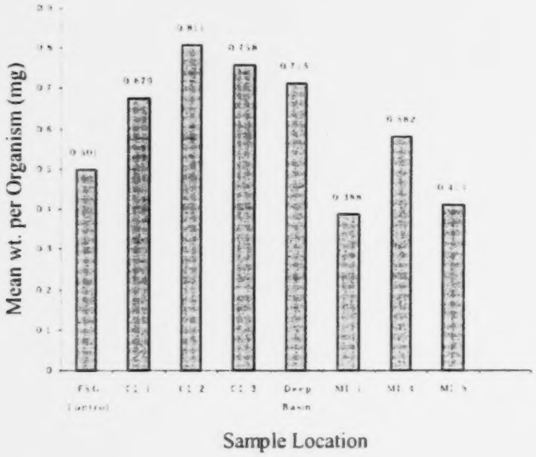
Substance	Date Collected	ESG Sample Number	Description
Control			-fine black sediment, no strong odour.
Consecon Lk. CL-1	04/26/99	03990547	-coarse, greenish-grey sediment, some organic material (mollusc shells), slight odour.
Consecon Lk. CL-2	04/26/99	03990546	-very fine, dark olive-green sediment, slight odour.
Consecon Lk. CL-3	04/26/99	03990544	-fine-coarse, dark olive-green sediment, large amounts of organic material (molluscs shells, wood), slight odour.
Consecon Lk. CL-Deep Basin	05/03/99	03990549	-fine dark green-grey sediment, slight odour.
Moira Lk. ML-1	04/22/99	03990551	-very fine black sediment, slight odour.
Moira Lk. ML-4	04/27/99	03990557	-fine, black sediment, slight odour.
Moira Lk. ML-5	04/27/99	03990556	-coarse, black sediment, large mounts of organic material (mollusc shells), slight odour

Results

Chironomus riparius Survival



Chironomus riparius Growth



SEDIMENT TEST REPORT

Chironomus riparius Survival and Growth Data

Station	Replicate	% Surviving Organisms	Overall Average % Survival	SD	CV	Mean Dry wt/Organism (mg)	Overall Average wt/organism (mg)	S.D.	CV
control	A	90	84	8.944	10.648	0.583	0.501	0.067	13.364
	B	90				0.433			
	C	70				0.433			
	D	80				0.514			
	E	90				0.543			
CL-1 03990547	A	90	84	18.166	21.626	0.688	0.679	0.169	24.923
	B	100				0.792			
	C	70				0.490			
	D	60				0.890			
	E	100				0.533			
CL-2 03990546	A	100	64	29.665	46.351	0.755	0.811	0.282	34.820
	B	60				0.490			
	C	60				0.812			
	D	20				1.265			
	E	80				0.731			
CL-3 03990544	A	60	56	40.373	72.095	0.955	0.758	0.365	48.181
	B	10				0.150			
	C	100				0.821			
	D	90				0.757			
	E	20				1.105			
CL-Deep Basin 03990549	A	100	94	8.944	9.515	0.682	0.715	0.148	20.701
	B	100				0.733			
	C	80				0.901			
	D	100				0.543			
	E	90				0.497			
ML-1 3990551	A	60	74	13.416	18.130	0.375	0.388	0.093	23.885
	B	60				0.297			
	C	90				0.444			
	D	80				0.515			
	E	80				0.307			
ML-4 3990557	A	100	78	30.332	38.887	0.577	0.582	0.061	10.561
	B	100				0.621			
	C	50				0.508			
	D	40				0.662			
	E	100				0.541			
ML-5 3990556	A	60	56	41.593	74.274	0.398	0.414	0.105	25.483
	B	90				0.563			
	C	0				0.000			
	D	30				0.317			
	E	100				0.376			

Technician : ____________________

Toxicity Test Chemistry Parameters

Sediment		Day					
		0	1	4	6	8	10
Control	Temp. (°C)	23.5	24.0	24.0	23.5	23.0	22.0
	D.O. (mg/L)	7.9	7.8	7.4	8.2	8.1	7.8
	pH	8.2					8.3
	Conductivity	536					599
	Ammonia (mg/L)	2.75					0.7
	Hardness (mg/L)	260					300
Consecon Lk. - CL-1 03990547	Temp. (°C)	23.5	24.0	24.0	23.5	23.0	22.0
	D.O. (mg/L)	8.1	7.9	8.2	7.8	8.0	8.0
	pH	8.2					8.3
	Conductivity	535					494
	Ammonia (mg/L)	0.95					0.5
	Hardness (mg/L)	260					230
Consecon Lk. - CL-2 03990546	Temp (°C)	23.5	24.0	24.0	23.5	23.0	22.0
	D.O. (mg/L)	8.2	8.1	8.1	7.6	8.0	7.8
	pH	8.3					8.2
	Conductivity	510					520
	Ammonia (mg/L)	0.6					0.6
	Hardness (mg/L)	260					300
Consecon Lk. - CL-3 03990544	Temp (°C)	23.5	24.0	24.0	23.5	23.0	22.0
	D.O. (mg/L)	8.3	8.1	8.3	7.5	5.3	5.6
	pH	8.0					8.2
	Conductivity	679					685
	Ammonia (mg/L)	0.65					1.9
	Hardness (mg/L)	300					310
Consecon Lk. - Deep Basin 03990549	Temp (°C)	23.5	24.0	24.0	23.5	23.0	22.0
	D.O. (mg/L)	8.0	8.1	8.1	7.8	8.0	8.1
	pH	8.2					8.2
	Conductivity	524					538
	Ammonia (mg/L)	1.5					0.6
	Hardness (mg/L)	260					270
Moira Lk. - ML-1 03990551	Temp. (°C)	23.5	24.0	24.0	23.5	23.0	22.0
	D.O. (mg/L)	7.6	8.1	8.3	7.4	8.2	8.2
	pH	8.3					8.1
	Conductivity	495					470
	Ammonia (mg/L)	1.05					0.6
	Hardness (mg/L)	260					260
Moira Lk. - ML-4 03990557	Temp. (°C)	23.5	24.0	24.0	23.5	23.0	22.0
	D.O. (mg/L)	8.5	8.3	7.9	7.3	7.9	7.4
	pH	8.4					8.0
	Conductivity	506					496
	Ammonia (mg/L)	0.55					1.25
	Hardness (mg/L)	260					240
Moira Lk. - ML-5 03990556	Temp. (°C)	23.5	24.0	24.0	23.5	23.0	22.0
	D.O. (mg/L)	8.4	8.3	8.1	6.9	8.1	7.1
	pH	8.3					8.1
	Conductivity	513					512
	Ammonia (mg/L)	0.7					1.3
	Hardness (mg/L)	270					280

Date:____________________

Approved by:_________________________
Jim Reid, Laboratory Supervisor

Test Conditions

Test Organism	*Chironomus riparius*	Sediment Volume (mL)	100
Source	University of Waterloo	Control/Dilution Water	undiluted well water[a]
Life Stage at Start	1st instar (<48h post hatch)	Overlying Water Volume (mL)	175
Test Type	Static	Test Aeration Rate	2-3 bubbles/second
No. Discrete Samples/Site	1	Photoperiod (h) light/dark	16/8
Number of Replicates	5	Temperature	23 ± 1 °C
Number of Organisms per Replicate	10	Feeding Rate	6 mg dry solids in 1.5 mL suspension / replicate
Number of Organisms per Treatment	50	Feeding Frequency	Daily
Sediment Depth	approx. 3.5 cm	Test Duration	10 days

a Control/Dilution Water: No chemicals added.

Test Protocol: Biological Test Method: Test for Survival and Growth in Sediment Using the Larvae of Freshwater Midges (*Chironomus tentans* or *Chironomus riparius*). Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/32.

Test Organisms: No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.

Control Sediment: Obtained from Long Point, Ontario.

Test Conditions: There were no unusual conditions or deviations from the test protocol.

Reference Toxicant Data

Substance	Copper (from copper sulphate)
Test Date	06 / 04 / 99
LC50 Survival (95% confidence limits)	176.8 μg/L (125 - 250)
Test Duration	96 hours
Historical Mean LC50	198.7 μg/L
Warning Limits (± 2 SD)	0 - 552.2
Statistical Method	Linear Interpolation (Toxstat 3.5)[a]

References

[a] West, Inc. and D. Gulley. 1996. Toxstat Release 3.5. Western Ecosystems Technology. Cheyenne, WY, U.S.A.

Sample Identification

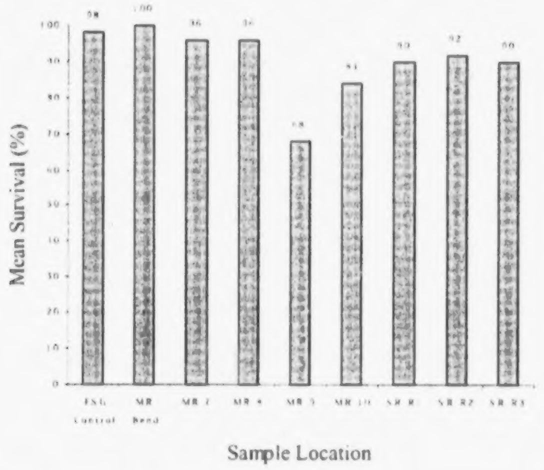
Company : Golder Associates
Location : Missassauga, ON
Sample Method : Grab
Sampled By : R. Yaagumagi
Date and Time Received : 05/10/99 @ 11 00

Date Tested : 06/08/99
Date Test Completed : 06/22/99
Shipped By : R. Yaagumagi
Lab Storage (°C) : 6.0
Sample Volume : 10 L

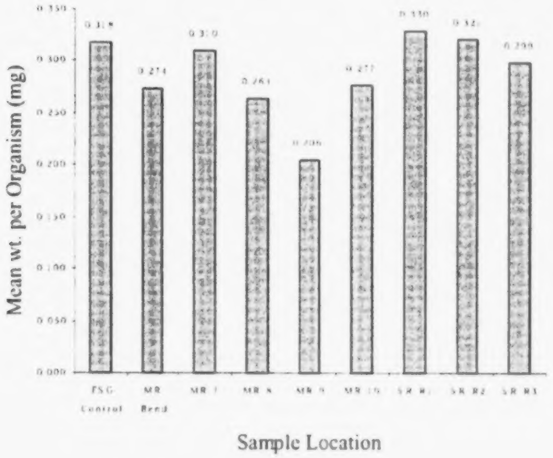
Substance	Date Collected	ESG Sample Number	Description
Control			-fine black sediment, no strong odour.
Moira R. MR-Bend Bay	04/27/99	03990568	-very fine, dark brown sediment, slight odour.
Moira R. MR-7	04/29/99	03990553	- fine, dark olive-brown sediment, some plant material, slight odour.
Moira R. MR-8 (Chisholm's Mills)	04/29/99	03990542	-fine, dark brown sediment (some lumps), some shells and plant material, slight odour.
Moira R. MR-9 (Latta)	04/29/99	03990543	-fine-coarse (sandy), dark brown sediment, large amount of plant material, some mollusc shells, strong odour.
Moira R. MR-10 (HWY 37)	04/29/99	03990552	- fine, dark brown-black sediment, little plant material, slight odour.
Salmon R. SR-R1	05/03/99	03990567	-very fine, olive-brown sediment, some plant material, slight odour.
Salmon R. SR-R2	05/03/99	03990566	-fine, dark brown sediment, large mounts of plant material, slight odour.
Salmon R. SR-R3	05/03/99	03990550	-fine, dark brown sediment (some rocks and pebbles), large amounts of plant material, faint odour.

Results

***Hyalella azteca* Survival**



***Hyalella azteca* Growth**



SEDIMENT TEST REPORT

Hyalella azteca and Survival and Growth

Station	Replicate	% Surviving Organisms	Overall Average Survival (%)	SD	CV	Mean Dry wt/Organism (mg)	Overall Average Dry wt/Organism (mg)	S.D.	CV
control	A	100	98	4.472	4.563	0.383	0.318	0.050	15.814
	B	100				0.305			
	C	90				0.280			
	D	100				0.266			
	E	100				0.358			
MR-Bend Bay 03990568D	A	100	100	0.000	0.000	0.317	0.274	0.038	14.034
	B	100				0.241			
	C	100				0.274			
		100				0.230			
	E	100				0.306			
MR-7 03990553D	A	100	96	5.477	5.705	0.329	0.310	0.030	9.825
	B	100				0.280			
	C	90				0.290			
		100				0.297			
	E	90				0.353			
MR-8 03990542D	A	100	96	5.477	5.705	0.287	0.264	0.041	15.397
	B	90				0.196			
	C	100				0.292			
		90				0.258			
	E	100				0.288			
MR-9 03990543D	A	80	68	16.432	24.164	0.263	0.206	0.047	22.628
	B	80				0.145			
	C	40				0.208			
		70				0.179			
	E	70				0.239			
MR-10 03990552D	A	80	84	16.733	19.920	0.333	0.277	0.047	16.777
	B	100				0.298			
	C	80				0.227			
		100				0.299			
	E	60				0.230			
SR-R1 03990567D	A	80	90	7.071	7.857	0.375	0.330	0.048	14.476
	B	100				0.338			
	C	90				0.324			
		90				0.361			
	E	90				0.252			
SR-R2 03990566D	A	90	92	4.472	4.861	0.308	0.321	0.044	13.627
	B	90				0.380			
	C	90				0.344			
		100				0.263			
	E	90				0.311			
SR-R3 03990550D	A	80	90	7.071	7.857	0.303	0.299	0.054	18.032
	B	90				0.249			
	C	90				0.351			
		90				0.240			
	E	100				0.353			

Technician : ____________________

SEDIMENT TEST REPORT

Hyalella azteca and Survival and Growth

Station	Replicate	% Surviving Organisms	Overall Average Survival (%)	SD	CV	Mean Dry wt/Organism (mg)	Overall Average Dry wt/Organism (mg)	S.D.
control	A	100	98	4.472	4.563	0.383	0.318	0.050
	B	100				0.305		
	C	90				0.280		
	D	100				0.266		
	E	100				0.358		
MR-Bend Bay 03990568	A	100	100	0.000	0.000	0.317	0.274	0.038
	B	100				0.241		
	C	100				0.274		
	D	100				0.230		
	E	100				0.306		
MR-7 03990553	A	100	96	5.477	5.705	0.329	0.310	0.030
	B	100				0.280		
	C	90				0.290		
	D	100				0.297		
	E	90				0.353		
MR-8 03990542	A	100	96	5.477	5.705	0.287	0.264	0.041
	B	90				0.196		
	C	100				0.292		
	D	90				0.258		
	E	100				0.288		
MR-9 03990543	A	80	68	16.432	24.164	0.263	0.206	0.047
	B	80				0.145		
	C	40				0.208		
	D	70				0.179		
	E	70				0.239		
MR-10 03990552	A	80	84	16.733	19.920	0.333	0.277	0.047
	B	100				0.298		
	C	80				0.227		
	D	100				0.299		
	E	60				0.230		
SR-R1 03990567	A	80	90	7.071	7.857	0.375	0.330	0.048
	B	100				0.338		
	C	90				0.324		
	D	90				0.361		
	E	90				0.252		
SR-R2 03990566	A	90	92	4.472	4.861	0.308	0.321	0.044
	B	90				0.380		
	C	90				0.344		
	D	100				0.263		
	E	90				0.311		
SR-R3 03990550	A	80	90	7.071	7.857	0.303	0.299	0.054
	B	90				0.249		
	C	90				0.351		
	D	90				0.240		
	E	100				0.353		

Technician : ____________________

Toxicity Test Chemistry Parameters

Sediment		Day						
		0	2	5	7	9	12	14
Control	Temp. (°C)	22.5	23.0	23.0	23.0	23.5	23.0	22.5
	D.O. (mg/L)	8.3	8.7	8.0	8.5	8.2	8.1	7.6
	pH	8.3						8.1
	Conductivity	497						523
	Ammonia (mg/L)	3.85						0.85
	Hardness (mg/L)	240						230
Moira R. - MR-Bend Bay	Temp. (°C)	22.5	23.0	23.0	23.0	23.5	23.0	22.5
03990568	D.O. (mg/L)	8.2	8.7	8.3	8.4	8.2	8.4	8.5
	pH	8.4						8.2
	Conductivity	488						534
	Ammonia (mg/L)	1.85						0.3
	Hardness (mg/L)	240						280
Moira R. - MR-7	Temp. (°C)	22.5	23.0	23.0	23.0	23.5	23.0	22.5
03990553	D.O. (mg/L)	8.5	8.8	8.3	8.2	8.3	8.2	7.8
	pH	8.3						8.0
	Conductivity	442						404
	Ammonia (mg/L)	0.35						0.4
	Hardness (mg/L)	230						210
Moira R. - MR-8	Temp. (°C)	22.5	23.0	23.0	23.0	23.5	23.0	22.5
03990542	D.O. (mg/L)	8.2	8.4	8.3	7.6	7.7	8.0	8.0
	pH	8.3						8.4
	Conductivity	501						558
	Ammonia (mg/L)	1.55						0.3
	Hardness (mg/L)	260						280
Moira R. - MR-9	Temp. (°C)	22.5	23.0	23.0	23.0	23.5	23.0	22.5
03990543	D.O. (mg/L)	7.7	8.7	8.0	7.9	7.7	7.5	7.8
	pH	8.3						8.1
	Conductivity	662						440
	Ammonia (mg/L)	4.75						0.45
	Hardness (mg/L)	340						200
Moira R. - MR-10	Temp. (°C)	22.5	23.0	23.0	23.0	23.5	23.0	22.5
03990552	D.O. (mg/L)	8.3	8.5	8.1	8.5	8.1	7.9	8.4
	pH	8.3						8.4
	Conductivity	518						584
	Ammonia (mg/L)	1.85						0.55
	Hardness (mg/L)	270						290
Salmon R. - SR-R1	Temp. (°C)	22.5	23.0	23.0	23.0	23.5	23.0	22.5
03990567	D.O. (mg/L)	8.3	9.0	8.6	8.4	8.0	8.3	8.3
	pH	8.2						8.4
	Conductivity	490						627
	Ammonia (mg/L)	0.55						0.55
	Hardness (mg/L)	260						340
Salmon R. - SR-R2	Temp. (°C)	22.5	23.0	23.0	23.0	23.5	23.0	22.5
03990566	D.O. (mg/L)	8.2	8.6	7.7	8.3	8.5	8.3	8.3
	pH	8.1						8.5
	Conductivity	548						626
	Ammonia (mg/L	1.1						0.45
	Hardness (mg/L)	240						340
Salmon R. - SR-R3	Temp. (°C)	22.5	23.0	23.0	23.0	23.5	23.0	22.5
03990550	D.O. (mg/L)	8.3	8.8	8.3	8.4	8.2	7.7	8.5
	pH	8.4						8.5
	Conductivity	426						516
	Ammonia (mg/L	1.5						0.3
	Hardness (mg/L)	250						270

Date:____________________

Approved by:________________________
Jim Reid, Laboratory Supervisor

Test Conditions

Test Organism	:	*Hyalella azteca*	Sediment Volume (mL)	:	100
Source	:	AIB, Burlington, ON	Control/Dilution Water	:	undiluted well water[a]
Life Stage at Start	:	2 - 9 day old	Overlying Water Volume (mL)	:	175
Test Type	:	Static	Test Aeration Rate	:	2-3 bubbles/second
No. Discrete Samples/Treatment	:	1	Photoperiod (h) light/dark	:	16/8
Number of Replicates	:	5	Temperature	:	23 ± 1 °C
Number of Organisms per Replicate	:	10	Feeding Rate	:	2.7 mg dry solids in 1.5 mL suspension / replicate
Number of Organisms per Treatment	:	50	Feeding Frequency	:	Daily
Sediment Depth	:	3.5 cm	Test Duration	:	14 days

a Control/Dilution Water: No chemicals added.

Test Protocol:	Biological Test Method: Test for Survival and Growth in Sediment Using the Freshwater Amphipod *Hyalella azteca*. Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/33.
Test Organisms:	No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test. Previous 48 hour culture mortality <1%.
Control Sediment :	Obtained from Long Point, Ontario.
Test Conditions:	There were no unusual conditions or deviations from the test protocol.

Reference Toxicant Data

Substance	:	Copper (from copper sulphate)
Test Date	:	06 / 10 / 99
LC50 Survival (95% confidence limits)	:	215.6 μg/L (159.8 - 288.6)
Test Duration	:	96 hours
Historical Mean LC50	:	207.6 μg/L
Warning Limits (± 2 SD)	:	66.2 - 346.1
Statistical Method	:	Linear Interpolation (Toxstat 3.5)[a]

References

[a] West, Inc. and D. Gulley. 1996. Toxstat Release 3.5. Western Ecosystems Technology. Cheyenne, WY, U.S.A.

Sample Identification

Company	: Golder Associates	Date Tested	: 06/04/99
Location	: Missassauga, ON	Date Test Completed	: 06/18/99
Sample Method	: Grab	Shipped By	: R. Yaagumagi
Sampled By	: R. Yaagumagi	Lab Storage (°C)	: 6.0
Date and Time Received	: 05/10/99 @ 11 00[a]	Sample Volume	: 10 L

Substance	Date Collected	ESG Sample Number	Description
Control			-fine black sediment, no odour.
Young's Ck. YC-1	04/28/99	03990541	-very fine, black sediment, some plant material, no odour.
Moira R. MR-R2	04/30/99	03990564	- fine, dark olive-brown sediment, large amounts of plant material (leaves, twigs), slight odour.
Moira R. MR-R3	05/12/99	03990565	-very fine, dark olive-brown sediment, slight odour. NOTE: seived through 500 μm to exclude macroorganisms and plant material
Moira R. MR-1	04/28/99	03990554	-fine, brown-black sediment, large amount of plant material, slight odour.
Moira R. MR-4	04/28/99	03990555	-fine, dark brown sediment, some plant material, slight odour.
Black R. BR-1	05/03/99	03990545	-fine to coarse (small pebbles), dark olive-brown sediment, some plant material, slight odour.
Skootamatta R. SR-1	05/03/99	03990561	-medium fine, dark olive-brown sediment, approximately 50% plant material (leaves, twigs), strong odour.

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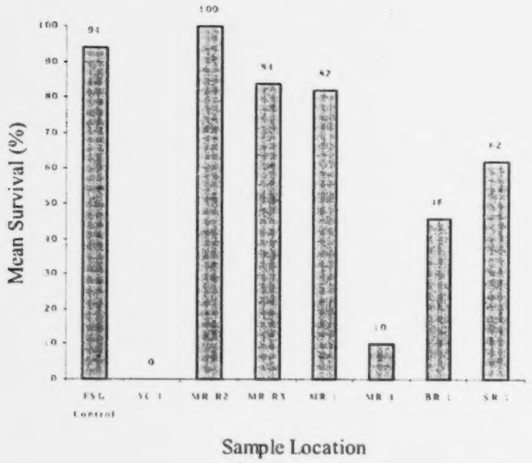
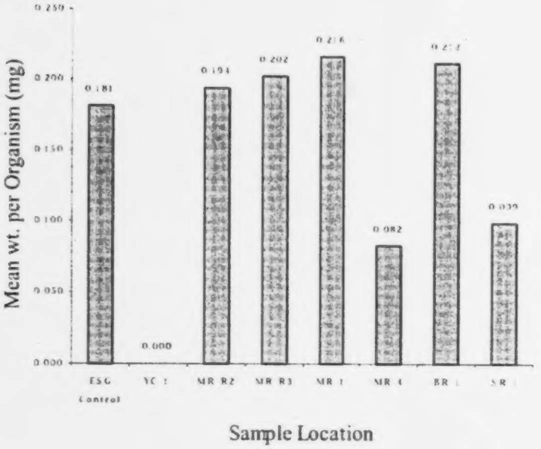
[a] Sample MR-R3 submitted May 14/99.

Results

***Hyalella azteca* Survival**



***Hyalella azteca* Growth**



SEDIMENT TEST REPORT

Hyalella azteca Survival and Growth

Station	Replicate	% Surviving Organisms	Overall Average % Survival	SD	CV	Mean Dry wt/Organism (mg)	Overall Average Dry wt/Organism (mg)	S.D.	CV
control	A	90	94	5.477	5.827	0.180	0.181	0.013	6.975
	B	90				0.176			
	C	90				0.173			
	D	100				0.203			
	E	100				0.173			
YC-1 03990541	A	0	0	0.000	0.000	0.000	0.000	0.000	0.000
	B	0				0.000			
	C	0				0.000			
	D	0				0.000			
	E	0				0.000			
MR-R2 03990564	A	100	100	0.000	0.000	0.195	0.194	0.011	5.645
	B	100				0.181			
	C	100				0.211			
	D	100				0.190			
	E	100				0.192			
MR-R3 03990565	A	90	84	18.165902	21.62607	0.211	0.202	0.042	20.613
	B	70				0.187			
	C	100				0.208			
	D	60				0.145			
	E	100				0.260			
MR-1 03990554	A	100	82	19.235	23.458	0.207	0.216	0.032	14.823
	B	50				0.248			
	C	80				0.165			
	D	90				0.231			
	E	90				0.229			
MR-4 03990555	A	0	10	14.142	141.421	0.000	0.082	0.054	66.381
	B	0				0.000			
	C	20				0.120			
	D	0				0.000			
	E	30				0.043			
BR-1 03990545	A	80	46	40.373	87.768	0.179	0.211	0.038	18.171
	B	50				0.178			
	C	0				0.000			
	D	90				0.239			
	E	10				0.250			
SR-1 03990561	A	60	62	14.832397	23.92322	0.122	0.099	0.019	19.116
	B	80				0.115			
	C	60				0.075			
	D	70				0.090			
	E	40				0.095			

Technician : ____________________

Toxicity Test Chemistry Parameters

Sediment		Day						
		0	3	5	7	10	12	14
Control Long Point, ON.	Temp. (°C)	22.0	22.0	23.0	23.0	23.0	23.0	23.5
	D.O. (mg/L)	8.7	4.8	7.9	8.9	8.4	8.3	8.1
	pH	8.4						8.2
	Conductivity	490						508
	Ammonia (mg/L)	3.95						[a]
	Hardness (mg/L)	250						240
Young's Ck.-YC-1 03990541	Temp. (°C)	22.0	22.0	23.0	23.0	23.0	23.0	23.5
	D.O. (mg/L)	8.3	8.3	8.2	8.0	8.4	8.1	7.6
	pH	8.0						6.9
	Conductivity	418						227
	Ammonia (mg/L)	3.0						0.53
	Hardness (mg/L)	150						120
Moira R.-MR-R2 03990564	Temp. (°C)	22.0	22.0	23.0	23.0	23.0	23.0	23.5
	D.O. (mg/L)	8.3	8.1	7.7	8.8	8.2	7.8	7.9
	pH	8.4						8.4
	Conductivity	603						580
	Ammonia (mg/L)	1.7						0.9
	Hardness (mg/L)	290						300
Moira R..-MR-R3 03990565	Temp. (°C)	22.0	22.0	23.0	23.0	23.0	23.0	23.5
	D.O. (mg/L)	8.5	8.1	7.7	8.7	8.3	8.1	8.1
	pH	8.5						8.6
	Conductivity	539						617
	Ammonia (mg/L)	3.85						0.45
	Hardness (mg/L)	380						360
Moira R.- MR-1 03990554	Temp. (°C)	22.0	22.0	23.0	23.0	23.0	23.0	23.5
	D.O. (mg/L)	7.8	8.1	6.0	8.9	8.2	7.9	7.8
	pH	8.2						8.5
	Conductivity	643						558
	Ammonia (mg/L)	2.3						0.25
	Hardness (mg/L)	330						330
Moira R. - MR-4 03990555	Temp. (°C)	22.0	22.0	23.0	23.0	23.0	23.0	23.5
	D.O. (mg/L)	7.2	8.9	8.2	8.8	8.3	8.3	8.2
	pH	8.3						8.6
	Conductivity	835						601
	Ammonia (mg/L)	5.45						0.43
	Hardness (mg/L)	380						350
Black R. - BR-1 03990545	Temp. (°C)	22.0	22.0	23.0	23.0	23.0	23.0	23.5
	D.O. (mg/L)	8.3	8.4	8.0	8.8	8.0	7.8	7.8
	pH	8.3						8.5
	Conductivity	559						564
	Ammonia (mg/L)	2.55						0.23
	Hardness (mg/L)	260						300
Skootamatta R.-SR-1 03990561	Temp. (°C)	22.0	22.0	23.0	23.0	23.0	23.0	23.5
	D.O. (mg/L)	7.5	8.6	7.7	8.9	8.4	7.9	8.1
	pH	8.2						8.2
	Conductivity	574						354
	Ammonia (mg/L)	4.85						0.48
	Hardness (mg/L)	300						260

[a] - not measured

Date:____________________

Approved by:____________________
Jim Reid, Laboratory Supervisor

Test Conditions

Test Organism	*Hyalella azteca*	Sediment Volume (mL)	100
Source	AIB, Burlington, ON	Control/Dilution Water	undiluted well water[a]
Life Stage at Start	2 - 9 day old	Overlying Water Volume (mL)	175
Test Type	Static	Test Aeration Rate	2-3 bubbles/second
No. Discrete Samples/Treatment	1	Photoperiod (h) light/dark	16/8
Number of Replicates	5	Temperature	23 ± 1 °C
Number of Organisms per Replicate	10	Feeding Rate	2.7 mg dry solids in 1.5 mL suspension / replicate
Number of Organisms per Treatment	50	Feeding Frequency	Daily
Sediment Depth	3.5 cm	Test Duration	14 days

a Control/Dilution Water: No chemicals added.

Test Protocol: Biological Test Method: Test for Survival and Growth in Sediment Using the Freshwater Amphipod *Hyalella azteca*. Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/33.

Test Organisms: No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test. Previous 48 h culture mortality <1%.

Control Sediment: Obtained from Long Point, Ontario.

Test Conditions: Sediment MR-R3 contained abundant small amphipods which could not be eliminated by hand picking. Sediment sample was sieved using a 500μm stainless steel mesh prior to testing. There were no other unusual conditions or deviations from the test protocol.

Reference Toxicant Data

Substance	Copper Sulphate
Test Date	06 / 04 / 99
LC50 Survival (95% confidence limits)	176.8 μg/L (125 - 250)
Test Duration	96 hours
Historical Mean LC50	206.9 μg/L
Warning Limits ($\pm$ 2 SD)	60.5 - 351.8
Statistical Method	Linear Interpolation (Toxstat 3.5)[a]

References

[a] West, Inc. and D. Gulley. 1996. Toxstat Release 3.5. Western Ecosystems Technology. Cheyenne, WY, U.S.A.

Sample Identification

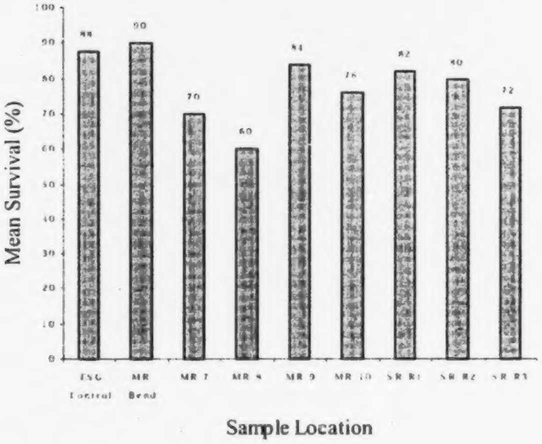
Company : Golder Associates
Location : Missassauga, ON
Sample Method : Grab
Sampled By : R. Yaagumagi
Date and Time Received : 05/10/99 @ 11 00

Date Tested : 06/23/ 99
Date Test Completed : 07/03/99
Shipped By : R. Yaagumagi
Lab Storage (°C) : 6.0
Sample Volume : 10 L

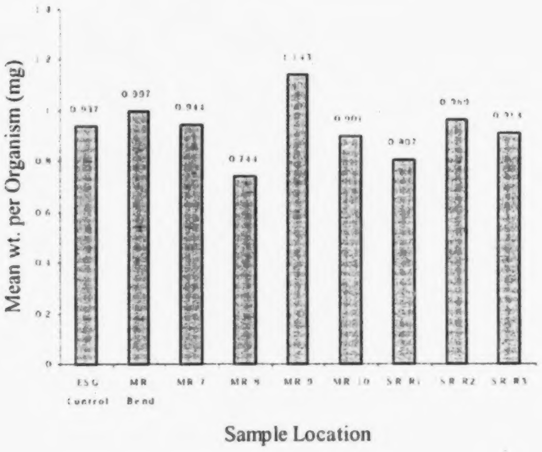
Substance	Date Collected	ESG Sample Number	Description
Control			-fine black sediment, no strong odour.
Moira R. MR-Bend Bay	04/27/99	03990568	-very fine, dark brown sediment, slight odour.
Moira R. MR-7	04/29/99	03990553	- fine, dark olive-brown sediment, some plant material, slight odour.
Moira R. MR-8 (Chisholm's Mills)	04/29/99	03990542	-fine, dark brown sediment (some lumps), some shells and plant material, slight odour.
Moira R. MR-9 (Latta)	04/29/99	03990543	-fine-coarse (sandy), dark brown sediment, large amount of plant material, some mollusc shells, strong odour.
Moira R. MR-10 (HWY 37)	04/29/99	03990552	- fine, dark brown-black sediment, little plant material, slight odour.
Salmon R. SR-R1	05/03/99	03990567	-very fine, olive-brown sediment, some plant material, slight odour.
Salmon R. SR-R2	05/03/99	03990566	-fine, dark brown sediment, large mounts of plant material, slight odour.
Salmon R. SR-R3	05/03/99	03990550	-fine, dark brown sediment (some rocks and pebbles), large amounts of plant material, faint odour.

Results

Chironomus riparius **Survival**



Chironomus riparius **Growth**



SEDIMENT TEST REPORT

Chironomus riparius Survival and Growth

Station	Replicate	% Surviving Organisms	Overall Average % Mortality	SD	CV	Mean Dry wt/Organism (mg)	Overall Average Dry wt/Organism (mg)	S.D.	CV
control	A	100	88	13.038	14.816	0.819	0.937	0.078	8.335
	B	90				1.034			
	C	80				0.925			
	D	100				0.942			
	E	70				0.966			
MR-Bend Bay 03990568	A	100	90	22.361	24.845	1.010	0.997	0.091	9.082
	B	50				0.980			
	C	100				0.863			
	D	100				1.115			
	E	100				1.019			
MR-7 03990553	A	70	70	15.811	22.588	0.840	0.944	0.223	23.668
	B	80				1.116			
	C	50				0.838			
	D	60				1.235			
	E	90				0.692			
MR-8 (Chisholm's Mills) 03990542	A	80	60	30.822	51.370	0.874	0.744	0.197	26.441
	B	20				0.505			
	C	50				0.752			
	D	50				0.600			
	E	100				0.989			
MR-9 (Latta) 03990543	A	90	84	18.166	21.626	1.133	1.143	0.136	11.932
	B	100				0.968			
	C	70				1.107			
	D	100				1.159			
	E	60				1.348			
MR-10 (Hwy 37) 03990552	A	80	76	15.166	19.955	0.840	0.901	0.099	11.009
	B	70				0.940			
	C	60				0.802			
	D	70				0.871			
	E	100				1.054			
SR-R1 03990567	A	100	82	13.038	15.900	0.720	0.807	0.085	10.511
	B	90				0.918			
	C	80				0.769			
	D	70				0.874			
	E	70				0.753			
SR-R2 03990566	A	100	80	15.811	19.764	0.935	0.969	0.076	7.850
	B	90				1.000			
	C	80				0.988			
	D	70				1.063			
	E	60				0.860			
SR-R3 03990550	A	100	72	25.884	35.950	1.093	0.913	0.261	28.597
	B	60				0.570			
	C	100				0.768			
	D	50				0.904			
	E	50				1.232			

Technician : ____________________

SEDIMENT TEST REPORT

Chironomus riparius Survival and Growth

Toxicity Test Chemistry Parameters

		Day					
Sediment		0	2	5	7	9	10
Control	Temp. (°C)	23.0	22.5	23.0	23.0	22.0	22.0
	D.O. (mg/L)	7.3	8.4	7.9	8.1	8.4	8.7
	pH	8.5					8.2
	Conductivity	482					545
	Ammonia (mg/L)	2.63					0.48
	Hardness (mg/L)	265					265
Moira R. - MR-Bend Bay 03990568	Temp. (°C)	23.0	22.5	23.0	23.0	22.0	22.0
	D.O. (mg/L)	8.4	8.3	7.8	8.3	8.5	8.6
	pH	8.3					8.1
	Conductivity	533					564
	Ammonia (mg/L)	1.90					0.68
	Hardness (mg/L)	280					300
Moira R. - MR-7 03990553	Temp (°C)	23.0	22.5	23.0	23.0	22.0	22.0
	D.O. (mg/L)	8.4	8.1	8.2	7.6	8.5	8.8
	pH	8.3					8.3
	Conductivity	440					423
	Ammonia (mg/L)	0.45					0.48
	Hardness (mg/L)	250					210
Moira R. - MR-8 03990542	Temp (°C)	23.0	22.5	23.0	23.0	22.0	22.0
	D.O. (mg/L)	6.2	8.4	8.2	8.4	8.6	8.4
	pH	7.8					8.4
	Conductivity	514					520
	Ammonia (mg/L)	2.0					5.95
	Hardness (mg/L)	275					240
Moira R. - MR-9 03990543	Temp (°C)	23.0	22.5	23.0	23.0	22.0	22.0
	D.O. (mg/L)	6.2	8.5	8.0	8.2	7.2	8.6
	pH	7.8					8.4
	Conductivity	625					527
	Ammonia (mg/L)	3.25					6.88
	Hardness (mg/L)	345					235
Moira R. - MR-10 03990552	Temp. (°C)	23.0	22.5	23.0	23.0	22.0	22.0
	D.O. (mg/L)	8.3	8.4	7.9	8.0	8.7	8.7
	pH	8.3					8.4
	Conductivity	529					512
	Ammonia (mg/L)	2.4					0.03
	Hardness (mg/L)	305					270
Salmon R. - SR-R1 03990567	Temp. (°C)	23.0	22.5	23.0	23.0	22.0	22.0
	D.O. (mg/L)	8.3	8.3	7.2	6.1	8.5	8.8
	pH	8.2					8.5
	Conductivity	519					485
	Ammonia (mg/L)	0.85					0.10
	Hardness (mg/L)	275					260
Salmon R. - SR-R2 03990566	Temp. (°C)	23.0	22.5	23.0	23.0	22.0	22.0
	D.O. (mg/L)	8.5	8.5	8.2	8.3	8.6	8.6
	pH	8.4					8.4
	Conductivity	540					562
	Ammonia (mg/L)	1.35					3.55
	Hardness (mg/L)	290					290
Salmon R. - SR-R3 03990550	Temp. (°C)	23.0	22.5	23.0	23.0	22.0	22.0
	D.O. (mg/L)	8.2	8.4	8.1	7.5	8.6	8.7
	pH	7.5					8.3
	Conductivity	495					475
	Ammonia (mg/L)	1.90					4.18
	Hardness (mg/L)	285					250

Date:___________________

Approved by:_______________________

Jim Reid, Laboratory Supervisor

Test Conditions

Test Organism	*Chironomus riparius*	Sediment Volume (mL)	100
Source	University of Waterloo	Control/Dilution Water	undiluted well water[a]
Life Stage at Start	1st instar (<48h post hatch)	Overlying Water Volume (mL)	175
Test Type	Static	Test Aeration Rate	2-3 bubbles/second
No. Discrete Samples/Site	1	Photoperiod (h) light/dark	16/8
Number of Replicates	5	Temperature	23 ± 1 °C
Number of Organisms per Replicate	10	Feeding Rate	6 mg dry solids in 1.5 mL suspension / replicate
Number of Organisms per Treatment	50	Feeding Frequency	Daily
Sediment Depth	approx. 3.5 cm	Test Duration	10 days

a Control/Dilution Water: No chemicals added.

Test Protocol: Biological Test Method: Test for Survival and Growth in Sediment Using the Larvae of Freshwater Midges (*Chironomus tentans* or *Chironomus riparius*). Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/32.

Test Organisms: No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.

Control Sediment: Obtained from Long Point, Ontario.

Test Conditions: Holding time exceeded 6 weeks.

Reference Toxicant Data

Substance	Copper (from copper sulphate)
Test Date	06 / 24 / 99
LC50 Survival (95% confidence limits)	88.4 μg/L (62.5 - 125.0)
Test Duration	96 hours
Historical Mean LC50	163.5 μg/L
Warning Limits (± 2 SD)	0 - 516.1
Statistical Method	Linear Interpolation (Toxstat 3.5)[a]

References

[a] West, Inc. and D. Gulley. 1996. Toxstat Release 3.5. Western Ecosystems Technology. Cheyenne, WY, U.S.A.

SEDIMENT TEST REPORT

Chironomus riparius Survival and Growth

Sample Identification

Company	:	Golder Associates	Date Tested	:	06/08/ 99
Location	:	Missassauga, ON	Date Test Completed	:	06/18/99
Sample Method	:	Grab	Shipped By	:	R. Yaagumagi
Sampled By	:	R. Yaagumagi	Lab Storage (°C)	:	6.0
Date and Time Received	:	05/10/99 @ 11 00[a]	Sample Volume	:	10 L

Substance	Date Collected	ESG Sample Number	Description
Control			-fine black sediment, no strong odour.
Young's Ck. YC-1	04/28/99	03990541	-very fine, black sediment, some plant material, no strong odour.
Moira R. MR-R2	04/30/99	03990564	- fine, dark olive-brown sediment, large amounts of plant material (leaves, twigs), slight odour.
Moira R. MR-R3	04/30/99	03990565	-very fine, dark olive-brown sediment, slight odour. NOTE: seived through 500 μm to exclude macroorganisms
Moira R. MR-1	04/28/99	03990554	-fine, brown-black sediment, large amount of plant material, slight odour.
Moira R. MR-4	04/28/99	03990555	-fine, dark brown sediment, some plant material, slight odour.
Black R. BR-1	05/03/99	03990545	-fine to coarse (small pebbles), dark olive-brown sediment, some plant material, slight odour.
Skootamatta R. SR-1	05/03/99	03990561	-medium fine, dark olive-brown sediment, approximately 50% plant material (leaves, twigs), strong odour.

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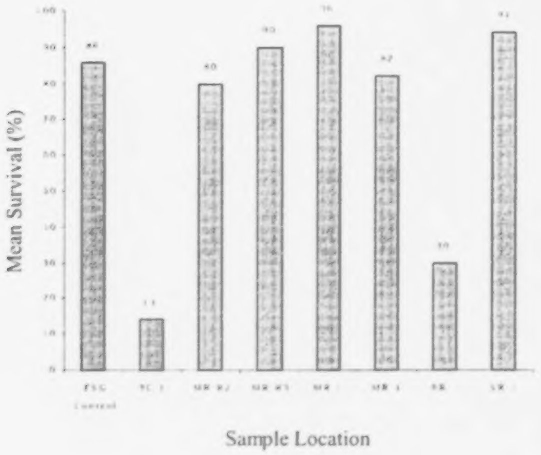
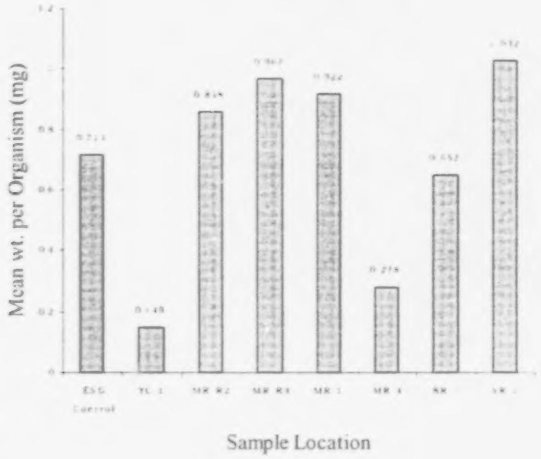
[a] sample MR-R3 submitted May 14, 1999

Results

***Chironomus riparius* Survival**



***Chironomus riparius* Growth**



SEDIMENT TEST REPORT

Chironomus riparius Survival and Growth

Station	Replicate	% Surviving Organisms	Overall Average % Survival	SD	CV	Mean Dry wt/Organism (mg)	Overall Average wt/Organism (mg)	S.D.	CV
control	A	90	86	5.477	6.369	0.672	0.714	0.135	18.960
	B	90				0.901			
	C	80				0.604			
	D	80				0.806			
	E	90				0.588			
YC-1 03990541	A	20	14	13.416	95.831	0.180	0.149	0.033	21.864
	B	20				0.115			
	C	30				0.153			
	D	0							
	E	0							
MR-R2 03990564	A	100	80	20.000	25.000	0.794	0.858	0.093	10.886
	B	70				0.739			
	C	90				0.943			
	D	90				0.858			
	E	50				0.954			
MR-R3 03990565	A	90	90	10	11.111	0.911	0.967	0.139	14.413
	B	100				0.847			
	C	80				1.021			
	D	100				0.871			
	E	80				1.186			
MR-1 03990554	A	100	96	8.944	9.317	0.925	0.922	0.085	9.255
	B	100				0.884			
	C	100				0.810			
	D	100				0.946			
	E	80				1.043			
MR-4 03990555	A	60	82	14.832	18.088	0.240	0.278	0.101	36.118
	B	80				0.264			
	C	100				0.318			
	D	90				0.149			
	E	80				0.421			
BR-1 03990545	A	40	30	31.623	105.409	0.780	0.652	0.275	42.193
	B	10				0.250			
	C	0				0.000			
	D	80				0.714			
	E	20				0.865			
SR-1 03990561	A	90	94	5.477	5.827	1.084	1.032	0.062	6.009
	B	90				1.000			
	C	100				0.941			
	D	90				1.046			
	E	100				1.088			

Technician : ____________________

SEDIMENT TEST REPORT

Chironomus riparius Survival and Growth

Toxicity Test Chemistry Parameters

Sediment		Day					
		0	1	3	6	8	10
Control	Temp. (°C)	22.0	23.0	23.0	23.5	23.0	23.5
	D.O. (mg/L)	8.4	8.0	8.8	7.9	8.2	8.1
	pH	8.3					8.2
	Conductivity	481					481
	Ammonia (mg/L)	2.50					0.35
	Hardness (mg/L)	240					230
Young's Ck.-YC-1 03990541	Temp. (°C)	22.0	23.0	23.0	23.5	23.0	23.5
	D.O. (mg/L)	8.8	7.9	8.7	7.9	8.1	8.3
	pH	8.0					7.4
	Conductivity	291					215
	Ammonia (mg/L)	2.8					0.35
	Hardness (mg/L)	140					90
Moira R.-MR-R2 03990564	Temp (°C)	22.0	23.0	23.0	23.5	23.0	23.5
	D.O. (mg/L)	8.6	6.1	8.8	8.1	8.2	8.0
	pH	8.5					8.3
	Conductivity	594					525
	Ammonia (mg/L)	2.3					0.4
	Hardness (mg/L)	280					250
Moira R..-MR-R3 03990565	Temp (°C)	22.0	23.0	23.0	23.5	23.0	23.5
	D.O. (mg/L)	8.4	7.5	8.7	7.6	7.7	7.5
	pH	8.4					8.2
	Conductivity	594					481
	Ammonia (mg/L)	3.6					0.4
	Hardness (mg/L)	320					260
Moira R.- MR-1 03990554	Temp (°C)	22.0	23.0	23.0	23.5	23.0	23.5
	D.O. (mg/L)	8.6	7.6	8.9	7.9	8.0	8.1
	pH	8.5					8.5
	Conductivity	573					484
	Ammonia (mg/L)	3.7					0.3
	Hardness (mg/L)	160					260
Moira R. - MR-4 03990555	Temp. (°C)	22.0	23.0	23.0	23.5	23.0	23.5
	D.O. (mg/L)	8.6	8.2	8.6	8.0	8.1	8.0
	pH	8.5					8.4
	Conductivity	661					622
	Ammonia (mg/L)	8.6					0.4
	Hardness (mg/L)	360					300
Black R. - BR-1 03990545	Temp. (°C)	22.0	23.0	23.0	23.5	23.0	23.5
	D.O. (mg/L)	8.6	7.9	8.9	7.6	7.7	7.6
	pH	8.5					8.3
	Conductivity	522					524
	Ammonia (mg/L)	7.5					5.95
	Hardness (mg/L)	160					250
Skootamatta R.-SR-1 03990561	Temp. (°C)	22.0	23.0	23.0	23.5	23.0	23.5
	D.O. (mg/L)	8.2	7.4	8.8	7.7	7.5	8.0
	pH	8.4					8.3
	Conductivity	552					406
	Ammonia (mg/L)	6.9					11.35
	Hardness (mg/L)	260					180

Date:____________________

Approved by:________________________

Jim Reid, Laboratory Supervisor

Test Conditions

Test Organism	: *Chironomus riparius*	Sediment Volume (mL)	:	100
Source	: University of Waterloo	Control/Dilution Water	:	undiluted well water[a]
Life Stage at Start	: 1st instar (<48h post hatch)	Overlying Water Volume (mL)	:	175
Test Type	: Static	Test Aeration Rate	:	2-3 bubbles/second
No. Discrete Samples/Site	: 1	Photoperiod (h) light/dark	:	16/8
Number of Replicates	: 5	Temperature	:	23 ± 1 °C
Number of Organisms per Replicate	: 10	Feeding Rate	:	6 mg dry solids in 1.5 mL suspension / replicate
Number of Organisms per Treatment	: 50	Feeding Frequency	:	Daily
Sediment Depth	: approx. 3.5 cm	Test Duration	:	10 days

a Control/Dilution Water: No chemicals added.

Test Protocol: Biological Test Method: Test for Survival and Growth in Sediment Using the Larvae of Freshwater Midges (*Chironomus tentans* or *Chironomus riparius*). Environment Canada, Conservation and Protection. Ottawa, Ontario. Report EPS 1/RM/32.

Test Organisms: No organisms exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.

Test Conditions: Sediment MR-R3 contained abundant small amphipods which could not be eliminated by hand picking. Sediment sample was sieved using a 500μm stainless steel mesh prior to testing. There were no other unusual conditions or deviations from the test protocol.

Reference Toxicant Data

Substance	: Copper (from copper sulphate)
Test Date	: 06 / 04 / 99
LC50 Survival (95% confidence limits)	: 176.8 μg/L (125 - 250)
Test Duration	: 96 hours
Historical Mean LC50	: 198.7 μg/L
Warning Limits (± 2 SD)	: 0 - 552.2
Statistical Method	: Linear Interpolation (Toxstat 3.5)[a]

References

[a] West, Inc. and D. Gulley. 1996. Toxstat Release 3.5. Western Ecosystems Technology. Cheyenne, WY, U.S.A.

Appendix III.3 Results of Toxicity Tests Using Fathead Minnow

EFFECTS OF MOIRA RIVER SEDIMENTS ON SURVIVAL AND GROWTH OF JUVENILE FATHEAD MINNOWS (*Pimephales promelas*)

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June 14, 1999

Executive Summary

A 21 day survival and growth test with juvenile fathead minnows (3 to 4 months old) was conducted on 28 sediment samples from the Moira River, Ontario. The test results, water quality monitoring data, and other supporting documentation are compiled in this report. Interpretation and application of the data to the collection areas are beyond the scope of this work.

1.0 Introduction

A twenty one day survival and growth test with juvenile fathead minnows (*Pimephales promelas*) was conducted on sediments from the Moira River, Ontario. The test was conducted following the Ontario Ministry of the Environment Laboratory Sediment Biological Testing Protocol (1992).

The method and test results are summarized in this report. All monitoring data collected during the 21 day test period are appended along with information on the samples. Quality assurance practices specific to the test are discussed in a separate section. Interpretation of the test data is beyond the scope of work and no attempt has been made to do any level of statistical analyses.

2.0 Test Method

A summary of the test method and conditions is attached (Table 1). The sediments were allowed to settle overnight and the pore water decanted. Each sediment was homogenized by hand mixing (kneading and rolling the sample bag). Three 325 mL aliquots were then removed and separately placed into two litre glass test vessels. Laboratory dilution water (dechlorinated City of Calgary water) was then added (1.3 L) and the test vessels placed onto shelves in a controlled environment room (Figure 1).

The colour and odour of the sediment and porewaters were recorded along with other observations. The pore water was also screened for toxicity with luminescent bacteria following a procedure based on Environment Canada's test method (Environment Canada, 1992). The results were expressed as a percent of controls. The pore waters were not toxic (data appended).

Gentle aeration with oil free compressed air was provided through a tube inserted in the lid of each vessel. The sediments were allowed to settle with aeration overnight. The test was then started with the addition of ten juvenile minnows to each vessel (3 to 4 months old).

The test was conducted at 20±2°C with a 16 hour light and 8 hour dark photoperiod. The light intensity at the surface of each test vessel was between 400 and 1000 lux. The test vessels were placed in a random fashion on the shelves. They were rotated weekly amongst the shelves to equalize exposure conditions.

There were three replicates of each sediment and duplicate sets run on every tenth sediment (HydroQual sample numbers 19990344-10, -20, and -29). The three control replicates were set up with a natural sediment collected from the Elbow River, Alberta and sieved to pass 500 µm.

Measurements of pH, conductance, dissolved oxygen, temperature, ammonium, hardness, and alkalinity were done at test initiation and termination on one of the three replicates. Conductance, pH, dissolved oxygen, and temperature were also measured on one replicate every Monday, Wednesday, and Friday throughout the test (different replicate measured each day). Conductance and pH were measured with portable Oakton meters. Dissolved oxygen and temperature were measured with a YSI Model 95 dissolved oxygen meter. Hardness and alkalinity were determined by titration with Hach reagent systems. Ammonium was measured with either the phenol-hypochlorite method or EM Quant dipsticks. Optical density measurements at test termination were made on water from each replicate with a Milton Roy spectrophotometer (750 nm).

Ammonium, nitrite (measured with EM Quant Dipsticks), pH, conductance, dissolved oxygen, alkalinity, and hardness were measured on the pore water at test initiation.

3.0 Results and Discussion

The sediments were shipped on May 5, 1999 and received on May 7, 1999 (sample 19990344-29 was received one week after the first shipment). The sediment samples arrived in good condition with all seals intact and the pails were stored at 4°C in darkness. They were assigned HydroQual sample numbers 19990344-1 to 29. Sample 19990344-29 was sent to replace sample number 19990344-2.

The sediments were mixed and dispensed on 1999/05/20. The test was initiated on 1999/05/21 and terminated on 1999/06/11. Mortality in the controls was 7% and all criteria were met for a valid test.

The final mortality and weight data are summarized in Table 2 and the initial and final chemical monitoring data in Table 3. All information collected during the conduct of this study is appended.

No standard deviations were calculated for samples that had complete mortality. Further, the fish from each replicate were weighed together, dried at 105°C for one hour and reweighed. In other words, individual fish weights were not measured. Hence, standard deviations could not be calculated for samples with fish surviving in two or less replicates.

Mortality across replicates was low during the first ten days of the test and then increased. Mortality was not related to measured increases in ammonia concentrations or any other changes in measured parameters. There was good agreement amongst replicates for each sediment sample. Coefficients of variation ranged from 1% to 17% with an average of 8%.

Coefficients of variation for the wet and dry weights ranged from 4% to 61% and from 3% to 86% respectively. The pooled average coefficients of variation were 17% and 19% for wet and dry weights respectively. The average moisture content was 82%.

The pH levels in the overlying water ranged from 7.4 to 8.0 at test initiation and from 7.6 to 8.2 at test termination. A small but significant increase in conductance was measured in all test vessels. The highest increase was in the controls but this had no effect on fathead minnow survival. Dissolved oxygen concentrations ranged from 6.4 to 7.2 mg/L at test initiation to 6.3 to 7.8 at test termination. Levels of dissolved oxygen were consistent amongst replicates and generally greater than 70% saturation at the test temperature. Temperatures amongst replicates throughout the test were 20±1°C.

Ammonium levels increased in each replicate during the test without any effect on the fathead minnows. The highest increase was in the controls, which had over 93% survival at test termination.

Hardness and alkalinity both increased during the test in most samples with no apparent effect on fathead survival. Hardness values ranged from 130 to 220 mg-$CaCO_3$/L at test initiation and from

145 to 520 at test termination. . Alkalinity values ranged from 130 to 170 mg-$CaCO_3$/L at test initiation and from 110 to 300 at test termination.

Duplicate sets of replicates were set up for HydroQual samples 19990344-10, -20, and -29 (marked a and b respectively). There was relatively good agreement amongst the average values for each set of duplicates. Final mortalities were within 20% of average values and the monitoring data were within the ranges of variation expected in tests of this nature (5 to 10% depending on the parameter).

The summary tables are presented in Section 5. All data collected during the course of this study are appended.

4.0 Reference:

Environment Canada. 1992. Biological Test Method: Toxicity Test using Luminescent Bacteria (*Vibrio fischeri*), EPS 1/RM/24.

Ontario Ministry of the Environment Laboratory Sediment Biological Testing Protocol, 1992 (reprinted 1995). Prepared by D. Bedard, A. Hayton, and D. Persuad Water Resources Branch, Ontario Ministry of the Environment, Queen's Printer for Ontario. ISBN 0-7729-9924-4.

5.0 Tables

Table 1. 21 Day Fathead Minnow Survival and Growth Test: Summary of Test Conditions

Test type:	static 21 day exposure to sediment (via overlying water)
Effects:	mortality
Endpoints:	percent mortality
Lighting:	photoperiod 16:8 hour light:dark
Temperature:	20°C+/-2°C
pH:	no adjustment
Aeration:	preaerate one hour minimum prior to addition of test organisms continuous during test; 2-3 bubbles per second
Test Vessel:	1.8 L vessel with 4 parts dechlorinated tap water to 1 part sediment
Test Volumes:	1300 mL water to 325 mL sediment
Replicates:	three
Loading:	10 minnows per vessel (0.08 minnows per cm^2)
Dilution water:	dechlorinated City of Calgary tap water (lab dilution water)
Control Sediment:	field collected from Bow River, Calgary, AB
Organisms:	*Pimephales promelas* size approx. 3-4 mth old
Feeding:	1-2 times per week; approx. 1% of wet weight; coarsely ground flake food in dechlorinated tap water; only feed if fish are feeding (do not over feed)
Measurements:	pH, conductivity, dissolved oxygen and temperature (3 times per week) hardness, alkalinity and ammonia at initiation and termination daily score of number of dead organisms (remove and discard dead)
Sample Treatment:	collect sample of overlying water (pore water) for analyses of pH, conductance, hardness, nitrites, and ammonium homogenize sediment and water and collect sample colour, odour, and % moisture decant excess water from sediment remove large debris homogenize sediment by mixing thoroughly
Reference:	Ontario Ministry of the Environment, Laboratory Sediment Biological Testing Protocol, 1992.(reprinted 1995)

Table 2. Summary of Test Results: Fish Mortality and Weights at Test Termination (21 d)

Sample Description		Mortality (%)			Weights (mg/fish)						Moisture Content (%)
HydroQual 19990344	Golder	avg	sd	cv	wet			dry			
					avg	sd	cv	avg	sd	cv	
Control	BR Sed	7	1	9	134	15	11	29	1	3	78
1	MR-10	73	4	5	128	25	20	22	nc	nc	83
2	ML-1	7	1	9	157	13	8	22	1	7	86
3	MR-1	30	4	15	200	122	61	27	13	48	87
4	SL-1	10	1	10	188	10	5	32	3	10	83
5	SL-3	50	4	9	147	6	4	21	2	9	85
6	SL-4	10	1	10	171	29	17	26	6	24	85
7	RL-1	100	nc	nc	nc	nc	nc	nc	nc	nc	nc
8	RL-2	53	4	8	141	23	16	20	5	27	86
9	RL-3	13	1	9	115	10	9	18	1	8	84
10a	CL-2	30	1	3	115	10	9	18	2	13	84
11	CL-1	17	1	7	151	26	17	27	6	24	82
12	CL-3	50	4	9	140	42	30	21	6	30	85
13	ML-4	57	4	7	163	38	23	28	2	8	83
14	ML-5	100	nc	nc	nc	nc	nc	nc	nc	nc	nc
15	MR-6	70	5	7	124	nc	nc	21	nc	nc	83
16	YC-1	70	5	7	173	nc	nc	27	nc	nc	84
17	MR-4	93	1	1	170	nc	nc	28	nc	nc	84
18	MR-8	43	5	11	148	43	29	22	2	7	85
19	MR-7	7	1	9	145	16	11	23	4	16	84
20a	MR-9	97	1	1	180	nc	nc	33	nc	nc	82
22	MR-R2	37	6	15	149	10	7	29	2	5	80
23	BR-1	100	nc	nc	nc	nc	nc	nc	nc	nc	nc
24	SR-1	73	5	6	156	nc	nc	25	nc	nc	84
25	SR-R1	67	6	9	113	nc	nc	20	nc	nc	82
26	SR-R2	67	3	5	175	25	14	29	1	2	84
27	SR-R3	20	1	5	142	17	12	26	6	23	82
28	CL-DB	7	1	17	154	19	12	24	1	5	84
29a	MR R3	87	2	2	145	35	24	92	79	86	37
10b	CL-2	53	5	8	189	41	22	29	2	5	85
20b	MR-9	100	nc	nc	nc	nc	nc	nc	nc	nc	nc
29b	MR R3	63	2	4	100	19	19	16	5	29	84

Note: nc, not calculated; avg, average; sd, standard deviation; cv, coefficient of variation

Table 3. Summary of Test Results: Water Quality Data

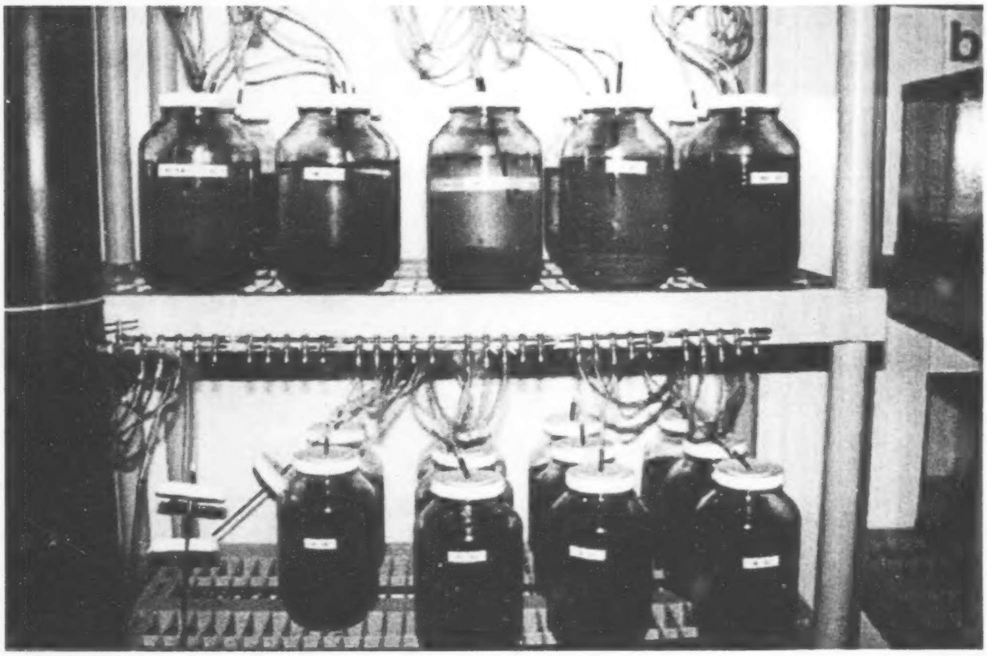
Sample Description		Initial Chemistry						Final Chemistry					
HydroQual 2E+07	Golder	pH (units)	cond (us/cm)	DO (mg/L)	temp (oC)	hardness (mg/L)	alkalinity (mg/L)	pH (units)	cond (us/cm)	DO (mg/L)	temp (oC)	hardness (mg/L)	alkalinity (mg/L)
Control	BR sed	7.9	440	6.4	21	170	130	8.0	1170	7.0	19	810	230
1	MR-10	7.9	420	6.9	21	184	136	8.2	650	7.4	20	245	210
2	ML-1	8.0	392	7.3	20	>200	150	8.2	649	7.5	20	190	220
3	MR-1	7.9	389	7.2	20	160	140	7.7	596	7.3	20	260	165
4	SL-1	7.9	367	7.2	20	160	120	7.7	516	6.7	20	145	160
5	SL-3	7.9	390	7.1	20	200	140	7.7	546	7.6	20	210	110
6	SL-4	7.8	357	7.1	20	160	130	8.2	501	7.8	20	145	140
7	RL-1	7.8	431	6.5	20	210	160	8.2	700	7.4	20	175	290
8	RL-2	7.9	351	7.2	20	220	110	8.2	616	7.7	20	190	200
9	RL-3	7.9	355	7.1	20	130	120	7.9	534	7.5	20	155	130
10a	CL-2	8.0	393	7.2	20	190	160	8.1	537	7.8	20	205	170
11	CL-1	7.8	400	7.0	20	200	170	7.9	533	7.8	20	220	190
12	CL-3	7.9	401	7.0	20	190	150	7.8	520	7.6	20	250	170
13	ML-4	7.9	406	7.2	20	200	160	8.1	653	7.3	20	250	230
14	ML-5	8.0	395	7.2	20	190	130	8.4	657	7.7	20	200	210
15	MR-6	7.9	387	7.2	20	200	150	8.2	669	7.7	20	205	200
16	YC-1	7.7	337	7.1	20	160	140	8.1	447	7.7	20	110	150
17	MR-4	8.0	443	6.8	20	210	170	7.6	639	6.3	20	320	240
18	MR-8	7.9	390	7.1	20	170	150	8.3	565	7.5	20	175	220
19	MR-7	8.0	361	7.2	20	124	145	7.9	499	7.2	20	170	150
20a	MR-9	7.9	403	7.1	20	180	160	7.6	590	7.5	20	235	220
22	MR-R2	7.6	412	6.8	20	190	170	7.7	560	7.5	20	205	130
23	BR-1	7.9	394	7.0	20	180	175	8.0	705	7.2	20	270	300
24	SR-1	7.9	369	6.9	20	170	135	8.0	551	7.6	20	190	240
25	SR-R1	7.9	383	7.2	20	175	140	8.0	556	6.7	20	260	200
26	SR-R2	8.0	395	7.1	20	170	140	8.2	687	7.3	20	225	290
27	SR-R3	7.4	375	6.5	20	190	150	8.1	573	7.7	20	225	230
28	CL-DB	8.0	403	7.0	20	195	140	8.1	615	7.8	20	225	160
29a	MR R3	8.0	535	6.0	21	150	140	8.1	630	7.8	20	325	190
10b	CL-2	8.0	394	7.1	20	200	150	8.1	636	7.6	20	225	240
20b	MR-9	8.0	405	7.0	20	200	150	8.3	725	7.7	20	275	280
29b	MR R3	8.0	382	7.1	20	140	145	8.0	617	7.4	20	320	240

Notes: cond, conductance; DO, dissolved oxygen; temp, temperature;avg, average; sd, standard deviation; cv, coefficient of variation

6.0 Figures

a. Photograph of the Test Vessels in the Controlled Environment Test Chamber
b. Clasp of One of the Test Vessels

a


b

7.0 Appendices

4. Monitoring Data for Fathead Minnow Test: Mortality Over Time
5. Monitoring Data for Fathead Minnow Test: Daily Log
6. Monitoring Data for Fathead Minnow Test: pH
7. Monitoring Data for Fathead Minnow Test: Conductance
8. Monitoring Data for Fathead Minnow Test:: Dissolved Oxygen
9. Monitoring Data for Fathead Minnow Test: Temperature
10. Monitoring Data for Fathead Minnow Test: Hardness, Alkalinity, Ammonium, and Optical Density
11. Supplementary Sample Information Data
12. Bacterial Luminescence Test Data on Porewater

Table 4. Monitoring Data for Fathead Minnow Test: Mortality over Time

Sample Description HydroQual 19990344	Golder	Day 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
Control	BR sed														1						1			2
1	MR-10															1			9	6	1	4	1	22
2	ML-1																				1		1	2
3	MR-1																		5	2	2			9
4	SL-1																		1				2	3
5	SL-3										1					3			7	3			1	15
6	SL-4																		1		1		1	3
7	RL-1														2				9	4	6	4	5	30
8	RL-2																		2	1	2	3	8	16
9	RL-3																			1	1		2	4
10a	CL-2									1						2			3	1			2	9
11	CL-1								1							1					1		1	4
12	CL-3																		5	6	4			15
13	ML-4													1	1					1	1	2	11	17
14	ML-5											2				1		6	9	2	9			29
15	MR-6																	3	4	3	4	4	3	21
16	YC-1											1							2	9	5		3	20
17	MR-4											3	1	8	3			2	2	6	1		2	28
18	MR-8														1				6	3	1		2	13
19	MR-7														2									2
20a	MR-9								1		1			2	2	5	4	6	6	1			1	29
22	MR-R2																		1	6	3		1	11
23	BR-1																		1	8	13	2	6	30
24	SR-1									1	1					1			5	12			2	22
25	SR-R1											1				1							18	20
26	SR-R2											1					2	5	5	1	2	3	1	20
27	SR-R3																		1	1	1		3	6
28	CL-DB																			1	1			2
29a	MR R3								1					2	1	1			11	6	1		2	25
10b	CL-2																		6			5	5	16
20b	MR-9									1	3					1	2	3	5	7	3		5	30
29b	MR R3									2		1				1			3	6	2		4	19

Table 4. Monitoring Data for Fathead Minnow Test: Mortality over Time (cont'd)

Sample Description			Day																						Totals
HydroQual	Golder	rep	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Control	BR sed	a																							0
		b														1									1
		c																				1			1
1	MR-10	a															1				3	1	4		9
		b																		3					3
		c																		6	3			1	10
2	ML-1	a																						1	1
		b																				1			1
		c																							0
3	MR-1	a																						0	0
		b																	4		2	2			8
		c																	1						1
4	SL-1	a																							0
		b																		1				1	2
		c																		1					1
5	SL-3	a										1					1								2
		b															1			2					3
		c															1			6	3				10
6	SL-4	a																						1	1
		b																							0
		c																		1		1			2
7	RL-1	a														2				1	3	2		2	10
		b																		8		1		1	10
		c																			1	1	4	4	10
8	RL-2	a																				1	1		2
		b																		1	1	1		1	4
		c																		1			3	6	10
9	RL-3	a																							0
		b																				1		1	2
		c																			1			1	2
10a	CL-2	a																		2					2
		b									1										1			2	4
		c															2			1					3

Table 4. Monitoring Data for Fathead Minnow Test: Mortality over Time (cont'd)

Sample Description			Day																						Totals
HydroQual	Golder	rep	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
11	CL-1	a																				1			1
		b															1								1
		c								1														2	3
12	CL-3	a																		1		1			2
		b																		1	1			1	3
		c																		3	5	2			10
13	ML-4	a													1	1					1	1		6	10
		b																						2	2
		c																					2	3	5
14	ML-5	a															1		3	3	1	1		1	10
		b											1						3	5		1			10
		c											1							1	1	7			10
15	MR-6	a																				4	4	2	10
		b																		1	1				2**
		c																	3	3	2			2	10
16	YC-1	a											1								1	5		3	10
		b																						1	1
		c																		2	8				10
17	MR-4	a												1	8				1						10
		b											2			3				1		1			7*
		c											1						1	1	6			1	10
18	MR-8	a																		1					1
		b																			1	1			2
		c														1				5	2			2	10
19	MR-7	a														1								0	1
		b														1									1
		c																							0
20a	MR-9	a								1		1			2	2	4								10
		b															1	4	4	1					10
		c																	2	5	1			1	9
22	MR-R2	a																							0
		b																		1	5	3		1	10
		c																			1				1

Note: * indicates 9 fish were added; ** indicates 11 fish were added

Table 4. Monitoring Data for Fathead Minnow Test: Mortality over Time (cont'd)+A30

Sample Description			Day																						Totals
HydroQual	Golder	rep	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
23	BR-1	a																			1	9			10
		b																			2	2	2	4	10
		c																		1	5	2		2	10
24	SR-1	a										1								4	5				10
		b									1									1	6			2	10
		c															1				1				2
25	SR-R1	a															1							9	10
		b											1											9	10
		c																							0
26	SR-R2	a																	1			1	1	1	4
		b																2	4	4					10
		c											1							1	1	1	2		6
27	SR-R3	a																		1	1	1			3
		b																						2	2
		c																						1	1
28	CL-DB	a																			1	1			2
		b																							0
		c																							0
29a	MR R3	a								1					2		1			2	2	1			9**
		b																		9				1	10
		c														1					4			2	7
10b	CL-2	a																						1	1
		b																		6			2	2	10
		c																					3	2	5
20b	MR-9	a									1	2						1	1		3	1		1	10
		b															1	1	1	4				3	10
		c										1							1	1	4	2		1	10
29b	MR R3	a									1						1			1	4	2			9
		b									1		1							1				2	5
		c																		1	2			2	5

Note: ** indicates 11 fish were added

Table 5. Monitoring Results for Fathead Minnow Test: Daily Log

Date	Day	Time	Technician (s)	Comments
1999/05/21	0	pm	S. Goudey/K. Brown/C. Schmidt/S. Rossi	Test Initiation
1999/05/22	1	pm	C. Schmidt	Routine monitoring/maintenance
1999/05/23	2	pm	C. Schmidt	Routine monitoring/maintenance
1999/05/24	3	pm	J. Hamilton/C. Schmidt	Routine monitoring/maintenance
1999/05/25	4	pm	K. Brown	Routine monitoring/maintenance
1999/05/26	5	pm	K. Brown	Routine monitoring/maintenance
1999/05/27	6	am	K. Brown	Routine monitoring/maintenance
1999/05/28	7	am	K. Brown	Routine monitoring/maintenance
1999/05/29	8	am	S. Rossi	Routine monitoring/maintenance
1999/05/30	9	am	S. Rossi	Routine monitoring/maintenance
1999/05/31	10	am	S. Rossi	Routine monitoring/maintenance
1999/06/01	11	am	K. Brown	Routine monitoring/maintenance
1999/06/02	12	am	K. Brown	Routine monitoring/maintenance
1999/06/03	13	am	K. Brown	Routine monitoring/maintenance
1999/06/04	14	am	K. Brown	Routine monitoring/maintenance
1999/06/05	15	am	K. Brown	Routine monitoring/maintenance
1999/06/06	16	am	K. Brown	Routine monitoring/maintenance
1999/06/07	17	am	J. Hamilton/C. Christie	Routine monitoring/maintenance
1999/06/08	18	am	C. Christie/J. Scott	Routine monitoring/maintenance
1999/06/09	19	am	J. Hamilton/C. Christie	Routine monitoring/maintenance
1999/06/10	20	am	C. Christie/J. Hamilton	Routine monitoring/maintenance
1999/06/11	21	pm	S. Rossi/K. Brown/J. Scott/C. Schmidt/S. Goudey	Test Termination

Table 6. Monitoring Data for Fathead Minnow: pH (units; all replicates were measured on day 21)

Sample Description		Day											
HydroQual 2E+07	Golder	0	3	5	7	10	12	14	17	19	21		
											a	b	c
Control	BR sed	7.9	7.9	7.8	7.9	7.9	8.1	8.0	8.2	8.1	8.0	8.2	7.9
1	MR-10	7.9	8.0	7.9	7.5	7.7	7.6	8.2	8.2	7.8	8.2	7.7	nd
2	ML-1	8.0	7.8	7.8	7.3	7.8	7.6	7.7	7.9	8.0	8.2	8.1	8.3
3	MR-1	7.9	7.9	7.8	7.4	7.9	8.1	8.0	8.2	8.0	7.7	7.8	8.0
4	SL-1	7.9	7.7	7.5	7.2	7.3	7.4	7.3	7.9	7.8	7.7	7.6	7.9
5	SL-3	7.9	8.0	7.4	7.6	7.7	8.0	8.0	8.2	7.8	7.7	7.5	nd
6	SL-4	7.8	7.4	7.1	7.1	7.4	7.4	7.6	7.8	8.0	8.2	7.9	7.8
7	RL-1	7.8	7.8	7.4	7.2	7.3	7.8	7.6	8.1	8.0	8.2	8.4	8.4
8	RL-2	7.9	7.8	7.6	7.4	7.6	7.8	7.6	7.9	8.0	8.2	8.2	8.2
9	RL-3	7.9	7.7	7.5	7.3	7.8	7.6	7.6	8.1	7.9	7.9	8.1	8.1
10a	CL-2	8.0	7.9	7.6	7.9	7.9	8.1	7.8	8.1	8.1	8.1	8.2	8.2
11	CL-1	7.8	8.0	7.9	7.6	7.8	7.7	7.8	8.2	7.7	7.9	7.9	7.9
12	CL-3	7.9	8.1	7.5	7.4	7.7	7.7	8.1	8.2	8.2	7.8	7.9	7.8
13	ML-4	7.9	7.8	7.4	7.7	8.0	7.7	7.4	8.0	8.1	8.1	8.1	8.1
14	ML-5	8.0	7.9	7.7	7.7	7.6	7.9	8.0	8.3	8.3	8.4	nd	8.2
15	MR-6	7.9	7.6	7.2	7.2	7.6	7.8	7.2	8.0	8.2	8.2	8.1	8.3
16	YC-1	7.7	7.6	7.2	7.1	7.5	7.5	7.8	7.9	7.8	8.1	7.9	nd
17	MR-4	8.0	7.9	7.6	7.7	7.8	7.9	8.0	7.9	8.2	nd	7.6	8.2
18	MR-8	7.9	7.9	7.7	7.4	7.0	7.4	8.1	8.2	8.4	8.3	8.1	8.3
19	MR-7	8.0	7.8	7.5	7.4	7.4	7.9	7.7	7.8	8.0	7.9	7.8	7.8
20a	MR-9	7.9	7.8	7.5	7.1	7.9	8.0	7.8	8.2	7.9	nd	nd	7.6
22	MR-R2	7.6	7.9	7.5	7.4	7.4	8.1	7.7	7.6	7.9	7.7	7.8	7.9
23	BR-1	7.9	7.8	7.6	7.4	7.6	7.6	7.5	7.8	8.3	nd	8.0	8.2
24	SR-1	7.9	7.7	7.8	7.7	7.9	7.8	8.0	8.1	7.8	8.0	8.2	8.0
25	SR-R1	7.9	7.9	7.7	7.2	8.2	7.7	7.5	8.1	7.8	8.0	8.0	8.1
26	SR-R2	8.0	8.0	7.6	7.6	8.1	7.7	8.1	8.4	8.2	8.2	nd	8.2
27	SR-R3	7.4	7.7	7.5	7.4	8.0	7.8	7.7	8.0	7.8	8.1	8.1	8.1
28	CL-DB	8.0	7.7	7.6	7.6	7.7	7.6	7.8	8.1	8.0	8.1	8.1	8.0
29a	MR R3	8.0	7.9	7.6	7.5	8.1	8.1	8.1	8.2	7.9	8.1	8.1	8.0
10b	CL-2	8.0	8.0	7.6	7.6	8.1	8.1	7.9	8.2	8.1	8.1	8.3	8.3
20b	MR-9	8.0	7.8	7.8	7.5	7.8	7.9	7.6	8.3	8.2	8.3	7.9	7.8
29b	MR R3	8.0	7.9	7.7	7.5	8.1	7.8	8.1	8.2	7.9	8.0	8.0	8.0

Notes: nd, not done

Table 7. Monitoring Data for Fathead Minnow: Conductance (us/cm; all replicates were measured on day 21)

Sample Description		Day									21		
HydroQual 19990344	Golder	0	3	5	7	10	12	14	17	19	a	b	c
Control	BR sed	440	671	384	1104	980	968	1266	1206	1068	1170	1280	1420
1	MR-10	420	389	381	518	523	580	610	663	627	650	614	nd
2	ML-1	392	383	381	548	499	552	591	619	608	649	629	638
3	MR-1	389	365	364	515	514	494	597	671	503	596	644	520
4	SL-1	367	330	314	444	407	404	486	492	454	516	485	458
5	SL-3	390	374	379	532	473	537	606	625	586	546	562	nd
6	SL-4	357	306	320	434	388	434	481	480	485	501	481	523
7	RL-1	431	388	390	591	571	512	651	677	564	700	682	608
8	RL-2	351	311	329	454	381	490	534	570	578	616	581	608
9	RL-3	355	327	320	405	455	429	469	586	509	534	587	540
10a	CL-2	393	401	418	498	465	502	539	581	554	537	567	570
11	CL-1	400	395	378	483	481	440	496	574	482	533	539	479
12	CL-3	401	404	419	513	513	636	540	607	654	520	551	545
13	ML-4	406	410	415	554	524	575	628	639	618	653	643	666
14	ML-5	395	389	403	587	551	535	645	643	573	657	nd	626
15	MR-6	387	382	349	591	553	579	647	657	607	669	662	634
16	YC-1	337	298	260	453	384	447	457	433	424	447	448	nd
17	MR-4	443	432	408	700	603	713	814	836	866	nd	639	807
18	MR-8	390	363	385	496	390	523	519	504	551	565	573	617
19	MR-7	361	334	412	435	385	441	467	473	501	499	457	503
20a	MR-9	403	427	441	703	639	616	770	708	654	nd	nd	590
22	MR-R2	412	403	412	603	580	593	669	713	607	560	582	576
23	BR-1	394	372	398	564	532	576	651	727	658	nd	705	683
24	SR-1	369	389	347	498	511	546	574	612	494	551	570	460
25	SR-R1	383	368	372	485	507	573	571	677	575	556	599	593
26	SR-R2	395	383	387	494	552	610	522	694	589	687	nd	650
27	SR-R3	375	333	348	453	417	454	490	526	480	573	525	440
28	CL-DB	403	433	435	588	561	610	618	641	585	615	633	616
29a	MR R3	535	384	384	540	576	592	664	787	641	630	652	620
10b	CL-2	394	392	385	522	506	520	580	640	404	636	623	620
20b	MR-9	405	418	409	612	540	591	711	686	633	725	650	612
29b	MR R3	382	378	396	554	522	595	647	665	615	617	573	569

Notes: nd, not done

Table 8. Monitoring Data for Fathead Minnow: Dissolved Oxygen (mg/L; all replicates were measured on day 21)

Sample Description HydroQual 19990344	Golder	Day 0	3	5	7	10	12	14	17	19	21 a	b	c
Control	BR sed	6.4	7.5	8.0	5.1	4.8	7.0	7.4	6.4	7.1	7.0	7.3	7.0
1	MR-10	6.9	7.2	8.4	4.0	4.8	5.3	6.8	6.2	6.9	7.4	7.5	nd
2	ML-1	7.3	7.5	8.7	3.5	4.8	6.3	6.7	6.6	7.6	7.5	7.5	7.6
3	MR-1	7.2	7.3	8.2	2.8	5.0	7.5	6.9	6.2	7.3	7.3	7.1	7.1
4	SL-1	7.2	7.5	8.2	2.8	4.7	6.7	6.9	6.7	7.5	6.7	6.7	7.2
5	SL-3	7.1	7.5	4.2	5.4	5.0	7.4	7.8	7.5	7.0	7.6	7.6	7.3
6	SL-4	7.1	7.0	5.4	4.2	4.6	6.5	7.0	7.1	7.3	7.8	7.6	7.6
7	RL-1	6.5	7.0	4.9	1.7	4.4	7.2	5.6	6.5	7.6	7.4	7.5	7.7
8	RL-2	7.2	7.3	5.3	5.4	5.2	7.3	6.0	6.1	7.4	7.7	7.5	7.5
9	RL-3	7.1	7.5	7.6	4.6	5.0	6.6	7.1	6.6	7.3	7.5	7.4	7.4
10a	CL-2	7.2	7.4	6.0	5.4	5.1	7.4	7.3	7.1	7.4	7.8	7.6	7.7
11	CL-1	7.0	7.5	8.2	5.0	4.7	6.5	7.6	6.4	7.9	7.8	7.4	7.5
12	CL-3	7.0	7.7	5.7	3.5	4.4	5.3	7.9	5.6	6.8	7.6	7.4	7.5
13	ML-4	7.2	7.4	3.0	6.3	4.0	6.8	6.9	7.2	6.8	7.3	7.4	7.6
14	ML-5	7.2	7.5	6.1	5.3	4.0	7.7	7.1	7.4	7.6	7.7	nd	7.6
15	MR-6	7.2	7.1	3.0	3.2	4.8	7.2	6.1	6.7	7.7	7.7	7.6	7.4
16	YC-1	7.1	7.3	4.7	3.0	4.5	7.2	6.1	7.0	7.3	7.7	6.0	nd
17	MR-4	6.8	7.1	6.4	3.7	4.8	6.1	8.0	6.7	7.3	nd	6.0	6.6
18	MR-8	7.1	7.6	7.5	2.6	4.4	6.5	6.7	5.5	7.5	7.5	7.3	7.1
19	MR-7	7.2	7.7	7.5	4.1	4.9	7.3	6.6	6.3	7.5	7.2	6.9	6.7
20a	MR-9	7.1	7.3	5.3	1.0	4.0	6.6	4.6	6.8	6.3	nd	nd	7.5
22	MR-R2	6.8	7.5	6.0	1.9	3.1	7.0	5.8	3.3	7.3	7.5	7.4	7.3
23	BR-1	7.0	7.4	5.5	1.9	3.4	6.4	4.1	4.9	7.3	nd	7.4	7.1
24	SR-1	6.9	6.7	7.0	4.5	4.9	6.6	7.3	7.2	7.2	7.6	7.4	7.4
25	SR-R1	7.2	7.3	6.2	4.1	5.0	5.8	6.7	6.5	7.0	6.7	6.9	7.3
26	SR-R2	7.1	7.4	5.4	4.0	4.5	5.6	7.1	7.5	7.5	7.3	nd	7.3
27	SR-R3	6.5	7.2	5.6	3.8	5.0	4.3	6.3	7.6	6.9	7.7	7.5	7.5
28	CL-DB	7.0	7.4	7.0	5.3	4.5	6.1	5.0	6.9	7.8	7.8	7.4	7.8
29a	MR R3	6.0	7.6	6.0	3.7	4.7	7.2	6.6	5.9	7.2	7.8	7.6	7.5
10b	CL-2	7.1	7.7	6.7	4.8	4.8	7.0	7.6	6.9	7.7	7.6	7.4	7.8
20b	MR-9	7.0	7.5	7.0	3.6	4.5	6.7	6.6	6.6	7.1	7.7	7.6	7.2
29b	MR R3	7.1	7.5	6.3	3.6	5.2	6.2	6.8	6.5	6.6	7.4	7.3	7.3

Notes: nd, not done

Table 9. Monitoring Data for Fathead Minnow: Temperature (°C; all replicates were measured on day 21)

Sample Description		Day											
HydroQual 19990344	Golder	0	3	5	7	10	12	14	17	19	21 a	 b	 c
Control	BR sed	21	19	20	20	20	20	20	20	20	19	20	20
1	MR-10	21	20	20	20	19	20	19	20	20	20	20	nd
2	ML-1	20	20	20	20	19	20	20	20	20	20	20	20
3	MR-1	20	20	20	20	19	20	20	20	20	20	20	20
4	SL-1	20	20	20	20	20	20	20	20	20	20	20	20
5	SL-3	20	20	20	20	19	20	19	19	20	20	20	nd
6	SL-4	20	20	20	20	19	20	19	19	20	20	20	20
7	RL-1	20	20	20	20	19	20	20	19	20	20	20	20
8	RL-2	20	20	20	20	19	20	20	20	20	20	20	20
9	RL-3	20	19	20	20	20	20	20	20	20	20	20	20
10a	CL-2	20	19	20	20	20	20	20	20	20	20	20	20
11	CL-1	20	19	20	20	20	20	20	20	20	20	20	20
12	CL-3	20	19	20	20	20	20	20	20	20	20	20	20
13	ML-4	20	20	20	20	19	20	20	20	20	20	20	20
14	ML-5	20	20	20	19	19	19	20	20	20	20	nd	20
15	MR-6	20	20	20	19	19	20	20	20	20	20	20	20
16	YC-1	20	20	20	20	19	20	20	20	20	20	20	nd
17	MR-4	20	20	20	20	19	20	19	20	20	nd	20	20
18	MR-8	20	19	20	20	19	20	20	19	20	20	20	20
19	MR-7	20	19	20	20	20	20	20	20	20	20	20	20
20a	MR-9	20	19	20	20	20	20	20	20	20	nd	nd	20
22	MR-R2	20	19	20	20	20	20	20	20	20	20	20	20
23	BR-1	20	19	20	20	20	20	20	20	20	nd	20	20
24	SR-1	20	19	20	20	20	20	20	20	20	20	20	20
25	SR-R1	20	20	20	20	20	20	20	20	20	20	20	20
26	SR-R2	20	20	20	20	20	20	20	20	20	20	nd	20
27	SR-R3	20	20	20	20	20	20	20	20	20	20	20	20
28	CL-DB	20	19	20	20	20	20	20	20	20	20	20	20
29a	MR R3	21	19	20	20	20	20	20	20	20	20	20	20
10b	CL-2	20	19	20	20	20	20	20	20	20	20	20	20
20b	MR-9	20	19	20	20	20	20	20	20	20	20	20	20
29b	MR R3	20	19	20	20	20	20	20	20	20	20	20	20

Notes: nd, not done

Table 10. Monitoring Data for Fathead Minnow Test: Hardness/Alkalinity/Ammonia and Optical Density

Sample Description		Hardness (mg/L)		Alkalinity (mg/L)		Ammonia (mg NH_4^+/L)		Optical Density
HydroQual 2E+07	Golder	Day 0	Day 21	Day 0	Day 21	Day 0	Day 21	Day 21
Control	BR Sed	170	810	130	230	<10	1	0.13
1	MR-10	184	245	136	210	<10	4	0.03
2	ML-1	>200	190	150	220	<10	9	0.15
3	MR-1	160	260	140	165	<10	6	0.04
4	SL-1	160	145	120	160	<10	9	0.04
5	SL-3	200	210	140	110	<10	8	0.02
6	SL-4	160	145	130	140	<10	14	0.1
7	RL-1	210	175	160	290	<10	15	0.02
8	RL-2	220	190	110	200	<10	6	0.06
9	RL-3	130	155	120	130	<10	10	0.04
10a	CL-2	190	205	160	170	<10	6	0.02
11	CL-1	200	220	170	190	<10	6	0.02
12	CL-3	190	250	150	170	<10	6	0.03
13	ML-4	200	250	160	230	<10	13	0.03
14	ML-5	190	200	130	210	<10	11	0.03
15	MR-6	200	205	150	200	<10	15	0.11
16	YC-1	160	110	140	150	<10	15	0.04
17	MR-4	210	320	170	240	<10	12	0.04
18	MR-8	170	175	150	220	<10	1	0.03
19	MR-7	124	170	145	150	<10	8	0.04
20a	MR-9	180	235	160	220	<10	9	0.02
22	MR-R2	190	205	170	130	<10	6	0.04
23	BR-1	180	270	175	300	<10	11	0.03
24	SR-1	170	190	135	240	<10	15	0.03
25	SR-R1	175	260	140	200	<10	3	0.04
26	SR-R2	170	225	140	290	<10	6	0.01
27	SR-R3	190	225	150	230	<10	25	0.05
28	CL-DB	195	225	140	160	<10	9	0.03
29a	MR-R3	150	325	140	190	<10	3	0.03
10b	CL-2	200	225	150	240	<10	6	0.03
20b	MR-9	200	275	150	280	<10	8	0.03
29b	MR-R3	140	320	145	240	<10	10	0.02

Table 11. Supplementary Sample Information Data

Sample Description HydroQual 19990344	 Golder	Collection Date	Sediment colour	odour	moisture (%)	Pore Water colour	 pH (units)	cond (uS/cm)	redox (mv)	hardness (mg CaCO3/L)	nitrites (mg NO_2^-/L)	ammonium (mg NH_3^+/L)
1	MR-10	1999/04/29	Dk Br	none	92	Cl	8.4	560	200	250	<2	<10
2	ML-1	1999/04/22	Md Br	none	50	P Yw	8.4	580	200	180	<2	<10
3	MR-1	1999/04/22	Gr Br	none	62	P Yw	8.4	520	200	120	<2	<10
4	SL-1	1999/04/22	Md Br	none	80	Cl	8.1	330	200	120	<2	<10
5	SL-3	1999/04/22	Md Br	none	44	Yw	8.3	500	200	120	<2	<10
6	SL-4	1999/04/22	Md Br	none	92	P Yw	8.0	370	200	120	<2	<10
7	RL-1	1999/04/23	Dk Br	none	92	Cl	8.1	770	200	180	<2	<10
8	RL-2	1999/04/23	Dk Br	none	92	Yw	8.2	290	200	80	<2	<10
9	RL-3	1999/04/23	Dk Br	none	92	Yw	7.9	340	200	120	<2	20
10a	CL-2	1999/04/26	Md Br	none	70	P Yw	8.4	630	200	180	<2	<10
11	CL-1	1999/04/26	Gr Br	none	72	Cl	8.2	520	200	120	<2	<10
12	CL-3	1999/04/26	Gr Br	none	58	Cl	8.2	570	200	180	<2	<10
13	ML-4	1999/04/27	Md Br	none	66	Cl	8.3	620	200	180	<2	<10
14	ML-5	1999/04/27	Gr Br	none	80	P Yw	8.2	570	200	120	<2	<10
15	MR-6	1999/04/27	Dk Br	none	90	P Yw	8.2	650	200	250	<2	<10
16	YC-1	1999/04/28	Dk Br	none	90	Cl	7.8	360	200	120	<2	<10
17	MR-4	1999/04/28	Lt Br-D	none	70	P Yw	8.3	750	200	120	<2	<10
18	MR-8	1999/04/29	Dk Br	none	90	P Yw	8.3	570	200	120	<2	<10
19	MR-7	1999/04/29	Md Br	none	74	P Yw	8.1	300	200	120	<2	<10
20a	MR-9	1999/04/29	Md Br-D	none	84	Yw	8.2	580	200	180	<2	<10
22	MR-R2	1999/04/30	Md Br-D	none	60	Cl	8.2	720	200	180	<2	<10
23	BR-1	1999/05/03	Md Br-D	none	90	P Yw	8.4	500	200	120	<2	<10
24	SR-1	1999/05/03	Md Br-D	none	76	Yw	8.3	320	200	80	<2	<10
25	SR-R1	1999/05/03	Md Br-D	none	78	Cl	8.4	540	200	120	<2	<10
26	SR-R2	1999/05/03	Dk Br-D	none	90	P Yw	8.4	740	200	120	<2	<10
27	SR-R3	1999/05/03	Dk Br-D	none	91	Cl	8.4	440	200	120	<2	<10
28a	CL-DB	1999/05/03	Gr Br	none	84	Cl	8.4	750	200	120	<2	<10
29	MR-R3	1999/05/12	Md Br	none	76	P Yw	8.3	580	200	180	<2	<10
10b	CL-2	1999/04/26	Md/Gr Br	none	70	P Yw	8.4	650	200	180	<2	<10
20b	MR-9	1999/04/29	Md/Gr Br-D	none	86	Yw	8.4	610	200	180	<2	<10
28b	CL-DB	1999/05/03	Gr Br	none	84	Cl	8.4	750	200	180	<2	<10

Notes: Br, brown; Dk, dark; Md, medium; Lt, light; Gr, grey; D, debris; Cl, clear; Yw, yellow; P, pale; nd, not done; cond, conductance; redox, reduction-oxidation potential

Table 12. Bacterial Luminescence Test Data on Pore Water

Sample number	Sample Description	Result (% controls)
19990344-1	MR-10	139
19990344-2	ML-1	136
19990344-3	MR-1	136
19990344-4	SL-1	130
19990344-5	SL-3	138
19990344-6	SL-4	135
19990344-7	RL-1	123
19990344-8	RL-2	137
19990344-9	RL-3	137
19990344-10a	CL-2	134
19990344-11	CL-1	132
19990344-12	CL-3	154
19990344-13	ML-4	150
19990344-14	ML-5	137
19990344-15	MR-6	138
19990344-16	YC-1	117
19990344-17	MR-4	115
19990344-18	MR-8	154
19990344-19	MR-7	136
19990344-20a	MR-9	136
19990344-21	MR-R1	141
19990344-22	MR-R2	145
19990344-23	BR-1	138
19990344-24	SR-1	129
19990344-25	SR-R1	149
19990344-26	SR-R2	154
19990344-27	SR-R3	144
19990344-28a	CL-Deep Basin	149
19990344-10b	CL-2	135
19990344-20b	MR-9	132
19990344-28b	CL-Deep Basin	133
19990344-29	MR-R3	115

APPENDIX IV

FISH TISSUE ANALYSIS AND WORK PLAN

Appendix IV.1 Fish Tissue Work Plan:
Collection of Fish Samples for Metal Analysis

1. INTRODUCTION

Alternatives for fish tissue analysis were discussed at the April 29, 1999 Steering Committee meeting. The lack of sufficient numbers of benthic invertebrates at the reference and exposed sites required that an alternative be developed for assessing the biological uptake of metals from stream sediments. Golder was asked to prepare recommendations regarding alternatives for tissue analysis, including a full rationale plus costs. It was requested that a discussion of whether the sex of fish affects metal uptake be included in the memo. In addition, specifics such as sample size per location were provided.

This document provides the rationale for and the details of the recommended scope of work.

2. RATIONALE

2.1 Suggested Changes to the Tissue Analysis Presented in the Golder Proposal

Metals and radionuclides accumulate to different degrees in different fish tissues. The literature suggests that some metals can accumulate to greater amounts in the kidney than in the liver. The literature also suggests that other tissues, such as gill, are often the primary sites of accumulation, depending upon the metal and that radionuclides usually collect primarily in bone tissue. Hence, we suggested in our proposal (Golder Associates 1999) that we re-visit the fish tissue component of the program as the RFP required that only the livers be analyzed for metals uptake.

The Golder proposal also suggested that specific radionuclides be analyzed instead of gross alpha and gross beta in order to provide more relevant information with respect to possible radiotoxicity.

2.2 Recommended Changes Based Upon Consultation with the Steering Committee and a More Thorough Review of the Literature

Radionuclides

Analysis for individual radionuclides does not appear to be warranted because of the very low levels of radioactivity detected in samples to date. We were under the impression when we prepared our proposal, that radionuclide levels could be substantially higher than background. Thus we suggested that analysis of individual radionuclides might provide a more accurate basis for screening of potential radiotoxicity risks to human health. We now suggest that individual radionuclide analysis would only be triggered if exposed fish have significantly higher levels of gross alpha and gross beta activity than reference fish. We note that in the unlikely event that such differences occur, laboratories equipped to perform neutron activation analysis for uranium and thorium can perform the analyses for a reasonable cost (e.g., Saskatchewan Research Council performs these analyses for about $25 per sample).

If analysis of individual radionuclides is warranted, bone is the recommended tissue to sample, particularly for radionuclides such as radium-226, which are analogous to calcium (Whicker and Schultz). Levels of uranium-series radionuclides in fish tissue are generally highest in bone, followed by skin, liver, gonad and muscle (Swanson 1985, Eisenbud 1987). Radionuclide uptake does not vary with fish age, size or sex (Swanson 1985).

Metals and Arsenic

There were two main objectives for the analysis of metals and arsenic in fish tissue:

1. Obtain levels in fish flesh for use in the human health risk assessment; and
2. Obtain exposure information for the sentinel species (i.e., to assess the degree of metals uptake in white suckers and longnose dace.)

The first objective is being met by the ongoing sport fish sampling conducted by the MOE, which we understand includes the analysis of muscle tissue for metals, arsenic and radionuclides. The second objective is the issue addressed in the paragraphs below.

Metals Uptake in Sentinel Fish Species

Development of quantitative links between exposure and effects is one of the most challenging aspects of effects monitoring and ecological risk assessment. Traditionally, researchers have used indirect indications of exposure (by measuring contaminant levels in water, sediment and food organisms). These indirect measures can be misleading when dealing with contaminants with poorly understood and/or complex bioavailability. In other words, it is often extremely difficult to predict the actual uptake of a contaminant from water or sediment data. Thus the analysis of tissue residues is highly desirable.

Although logical, the application of a tissue residue approach to exposure characterization is complex. First, there should be an understanding of the mechanisms or modes of action for the chemical of concern, such that appropriate tissues are sampled. For example, in order to define robust residue-based effects relationships for cationic metals, it may be necessary to focus upon tissues or sites of action (e.g., gill) that are not routinely sampled (Wood *et al.* 1997). Alternatively, even though such relationships may not allow determination of mechanistic processes, it might be possible to derive useful correlations between some internal chemical residue for metals and observed effects (Wood *et al.* 1997). Therefore, the challenge for the Moira River Study is to be sure that we select the appropriate tissue in order to allow a reasonably confident analysis of relationships between tissue residue levels and observed effects.

Selection of Appropriate Tissues for Analysis

Selection of appropriate tissues can be specific to the contaminant. For example, the appropriate tissue for arsenic may be different than that for copper or zinc. Existing water quality data for the Moira River system indicates that the primary contaminant of concern is arsenic.

The majority of studies linking tissue level with effects use whole-body analysis of arsenic (Jarvinen and Ankely 1999). For example, McGeachy and Dixon (1990, 1992) reported whole body levels of sodium arsenate along with survival or growth endpoints for rainbow trout. Cockell and Hilton (1988) reported "Carcass" residues of arsenic trioxide and survival and growth endpoints. Sorensen (1976) reported whole body, liver, gut, and muscle residues of sodium arsenate (As^{+5}) in green sunfish along with survival endpoints. Gilderhus (1966) reported whole body levels of sodium arsenite (As^{+3}) in bluegill, along with survival and growth endpoints.

On the basis of the existing literature linking tissue residues with effects, we recommended that whole body analyses be conducted for arsenic in both white sucker and longnose dace. This allowed for a comparison of results with a longer list of literature values and a more comprehensive database linking residues with effects than for liver analysis only.

Metals Analysis

Metals analyzed in fish tissue included: Ag, Al, Co, Cu, Ni, Pb and Zn (Kilgour *et al.* 1999). Copper accumulates to a greater extent in liver than in most other tissues, and linkages between liver residues and effects on growth and survival have been made by several authors (Jarvinen and Ankley 1999). However, linkages between whole-body residues of copper and effects are also available in the literature (Jarvinen and Ankely 1999). Whole-body, liver and gill residues of zinc appear to be similar in several studies of fish (Jarvinen and Ankley 1999). Linkages between zinc residues in whole body, liver, gill and kidney and growth, reproduction and survival endpoints are available (Jarvinen and Ankley 1999). Nickel appears to accumulate primarily in gill tissue and in kidney, although liver, muscle and whole body residues are also significant (Jarvinen and Ankley 1999). The only linkage between nickel tissue residue and effect is for survival. Whole body appears to be a reliable predictor of other tissue levels of aluminum (Jarvinen and Ankely 1999). Linkages are available between whole body residues of aluminum and survival. The only data on the linkage between silver tissue residues and effects are for whole body, gill and "internal organs" data (Coleman and Cearley 1974). Lead appears to accumulate preferentially in kidney and spleen, although liver and gill tissues also can contain significant amounts (Jarvinen and Ankley 1999). Linkages between tissue residues and effects have been made for liver, kidney, gill, spleen, and whole body data. There are no data linking tissue residues of cobalt and effects.

As can be seen by the above review, literature values for linkages between whole body analysis and effects are available for all of the metals of concern in the Moira system except for cobalt. Other tissues are often analyzed, but not necessarily the same tissues across several metals. Furthermore, whole body residues will be appropriate for arsenic.

The original study design called for tissue residue analysis in white sucker and in composite invertebrate samples. As recorded in the Minutes of the April 29, 1999 meeting, it will not be possible to analyze invertebrate samples because of the lack of sufficient numbers of invertebrates at the sampling stations. Small-bodied fish can be considered as an alternative to invertebrates because they are in close contact with sediments (this point is also recorded in the Minutes). Furthermore, information about exposure to the chemicals of concern in the other sentinel fish species will be very valuable.

Based upon the above review, we recommended that:

(1) Whole body residues of metals and arsenic are determined for the Moira River Study; and,

(2) residues are determined in longnose dace as well as in white sucker.

Influence of Fish Age, Size, and Sex

Rate of arsenic uptake is greatest in young fish; residues in both liver and muscle decline with size in almost all species (Moore and Ramamoorthy 1984). Depuration of most arsenic compounds from fish tissues is rapid. Barrows *et al.* (1980) reported that the half-life of As_2O_3 in bluegill muscle was only 1 day. Similarly, there was an 80% reduction in arsenic residues in whole rainbow trout within 96 hours of administration of an oral dose of ^{74}As (Oladimeji *et al.* 1979). Based upon this information, arsenic residues in white sucker and longnose dace from the Moira River system are not expected to be significant and may be higher in the longnose dace than in sucker.

Residues of copper in muscle tissue frequently decline with age and size of fish, but residues in liver have been shown to be positively correlated with fish age (Moore and Ramamoorthy 1984). There is usually little accumulation of lead in marine and freshwater species of fish, except in cases of extreme pollution (Moore and Ramamoorthy 1984). Furthermore, there is usually no correlation between lead residues and age or size of fish. There are few data relating the age/size of fish to nickel levels in fish; however, muscle residues either increase or remain constant as the fish grows (Moore and Ramamoorthy 1984). Zinc residues in freshwater and marine fish are generally much lower than those found in algae and invertebrates. Although there is often no correlation between residues in muscle and age/size of fish, uptake of zinc by young fish is generally greater than that of old fish. Most species show a seasonal variation in zinc levels in muscle and organs, with peaks during the spring and early summer (Moore and Ramamoorthy 1984). Aluminum, cobalt and silver uptake in fish is not well studied. Concentrations of silver in white sucker liver were correlated with sediment concentrations in the Lower Susquehanna River Basin (Lindsey *et al.* 1998). Liver tissue of smallmouth bass had higher concentrations of aluminum and cobalt that white sucker liver. White sucker liver had higher concentrations of silver than smallmouth bass (Lindsey *et al.* 1998). Therefore, there may be significant differences among fish species and metals with respect to relative uptake of aluminum, cobalt and silver from sediments. No information on uptake with age or size of fish is available.

The above literature suggests that there is a relationship between body burden of some of the contaminants of concern in the Moira River system and fish size or age. Therefore, analysis of body burden versus size/age was recommended in this study.

There are no data to suggest that there is a difference in uptake of arsenic or metals with sex of fish.

3. SCOPE OF WORK

The fish tissue analysis program was undertaken by collecting white sucker and longnose dace from sites located throughout the Moira River system.

Longnose dace is a small-bodied riverine species and as such was collected from the following river sites:

- Moira River half way between the mine site and Bend Bay;
- Moira River above the mine site; and
- Black River.

White sucker was collected from lakes and larger sections of the Moira River including:

- Moira River at Bend Bay;
- Moira River (3 stations downstream of Stoco Lake);
- Moira Lake;
- Stoco Lake;
- Consecon Lake; and
- Round Lake.

The collection of these fish species at these locations corresponds to the requirements of the fish population survey, which was conducted at the same time. The MOE collected the white sucker samples, as presented in the original RFP, and Golder collected the longnose dace samples.

Ten specimens of white sucker and 10 composite samples of longnose dace were taken and analyzed for arsenic, metals and gross alpha/gross beta activity. The sample size of 10 has been shown to be adequate to distinguish "exposed" from reference sites in other studies (radionuclides and metals) (Swanson 1985, U.S. EPA 1993). This sample size has been shown to distinguish differences of approximately 30-35% for uranium-series radionuclides (Swanson 1985) and approximately 10-20% for metals (assuming a mean: variance ratio of 0.5-1.0) (U.S. EPA 1993).

The 10 samples of white sucker were individual fish. Each of the longnose dace samples consisted of a 9 to 10 individuals. Whole-fish samples (gutted) were analyzed, rather than specific tissues (see above rationale).

Two size-classes of white sucker were selected for analysis (5 specimens from each size class). The first size-class represented the younger, faster-growing fish (with potentially greater arsenic or metal uptake). The first size-class was 10-30 cm (fork length). The second size class was > 30 cm. Nine to 10 individuals were collected from each sample class. This provided greater statistical power within each size class.

Supporting information accompanying the fish samples taken for analysis included:

- Full documentation of the sample location (UTM coordinates);
- Water depth, approximate water velocity, water temperature;
- Site name/number;
- Fish species and sample type (whole or composite, size-class);
- Fresh weight and fork length;
- External condition of the fish (any lesions, injuries, deformities will be noted);
- Internal condition of the fish, including sex and reproductive stage, presence of parasites, and any abnormal tissues or lesions;
- Age (aging materials will be taken from each specimen);
- Name of person taking the sample; and
- Habitat mapping at the longnose dace collection sites.

A detailed Technical Procedure for sampling fish for metals and radionuclides is provided in this Appendix (see attached Technical Procedure 8.16-0).

Samples will be frozen and shipped to the analytical laboratory for analysis.

PROTOCOL FOR PREPARATION OF WHOLE FISH SAMPLES FOR METALS ANALYSIS: MOIRA RIVER STUDY

1. Thaw specimens. Start with reference fish (Round Lake and Consecon Lake). Thaw only as many as you have time to process that day.

2. Knives to be used: high-quality, corrosion-resistant stainless steel knives must be used. Initial wash: wash with a detergent solution, rinse with tap water, soak in 50% HNO_3 for 24 hours at room temperature, and rinse with distilled water. All knives must be washed with a detergent solution, rinsed with tap water, rinsed in 50% HNO_3 for 15 minutes and rinsed with distilled water between each fish. All washed knives must be wrapped in heavy plastic wrap during storage.

3. Cleaning of the food processor blades: as above for knives.

4. Cleaning of the food processor plastic bowl, stainless steel bowls used during homogenization, spatulas used to transfer from processor-to-bowls and from bowl-to-glass vials and the glass vials used to store aliquots of the homogenized fish: Initial wash – wash with a detergent solution, rinse with tap water, soak in 50% HNO_3 for 24 hours at room temperature, and rinse with distilled water. Between each fish (food processor bowl, stainless steel bowls and spatulas) – wash with a detergent solution, rinse with tap water, rinse in 50% HNO_3 for 15 minutes at room temperature, and rinse with distilled water.

5. Preparation of fish for processing: cut the thawed fish into equally-sized pieces that will fit into the food processor bowl without jamming. The fish should be cut horizontally (cross-sections). If the fish is too big to process in one batch, place the processed portion in a stainless steel bowl and proceed with the next portions until done. Stir the contents of the stainless steel bowl thoroughly with a plastic or stainless steel spatula. Re-process the contents of the bowl 5 times.

6. Once the entire fish has been homogenized at least 5 times, place a 50 g aliquot of the homogenized fish into an acid-washed glass container.

7. Label with an indelible glass marker which has ink that is resistant to freezing. Also place a label inside each vial on waterproof paper labelled with indelible ink. The outside and inside labels must contain the following information: Species (WHSC); Site Code; Specimen Number; Date of Capture; Project Number; Project Name (Moira R. Study); and, "Golder Associates".

8. Freeze the sample. Freeze the remaining homogenized fish in a heavy-duty plastic bag with internal and external labels.

9. Enter the information on the chain-of-custody form (Len Rozon has these forms) as required: (sign the sample in for processing and out again for sending to the MOE lab).

10. Once all homogenates have been prepared, ship to MOE laboratory in a cooler with dry ice, properly labelled and packaged to comply with TDG regulations.

References

Barrow, M.E., S.R. Petrocelli, K.J. Macek and J.J. Carroll. 1980. Bioconcentration and elimination of selected water pollutants by Bluegill Sunfish (*Lepomis macrochirus*). In: R. Haque (Ed.), Dynamic exposure and hazard assessment of toxic chemicals. Ann Arbor Science, Ann Arbor, pp. 379-392.

Cockell, KA and JW Hilton. 1988. Preliminary investigations on the comparative chronic toxicity of four dietary arsenicals to juvenile rainbow trout. Aquat. Toxicol. 12: 73-82.

Coleman, RL and JI Cearley. 1974. Silver toxicity and accumulation in largemouth bass and bluegill. Bull. Environ. Contam. Toxicol. 12:53-61.

Eisenbud, M. 1987. Environmental radioactivity: from natural, industrial and military sources (3rd ed.). Academic Press Inc., FL.

Golder Associates. Proposal: Impact study of the Moira River system downstream of the former Deloro Mine site, Tender Number 004604. March 15, 1999.

Gilderhus, PA. 1966. Some effects of sublethal concentrations of sodium arsenite on bluegills and the aquatic environment. Trans. Am. Fish. Soc 95: 289-296.

Jarvinen, A.W. and G.T. Ankley. 1999. Linkage of effects to tissue residues: development of a comprehensive database for aquatic organisms exposed to inorganic and organic chemicals. SETAC Technical Publication Series. SETAC Press. Society of Environmental Toxicology and Chemistry, Pensacola, FL.

Kilgour, B.W., C.B. Portt and D.G. Dixon. 1999. Moira River Impact Study: Detailed design to determine the impact of the former Deloro Mine site on the Moira River System. Final Report submitted to Ontario Ministry of Environment.

Lindsey, B.D., K.J. Breen, M.D. Bilger and R.A. Brighthill. 1998. Water quality in the Lower Susquehanna River Basin, Pennsylvania and Maryland, 1992-1995. U.S. Geological Survey Circular 1168.

McGeachy, SM and DG Dixon. 1990. Effect of temperature on the chronic toxicity of arsenate to rainbow trout. Can. J. Fish Aquati. Sci. 47: 2228-2234.

McGeachy, SM and DG Dixon. 1992. Whole-body arsenic concentrations in rainbow trout during acute exposure to arsenate. Ecotoxicol. Environ. Saf. 24: 301-308

Moore, J.W. and S. Ramamoorthy. 1984. Heavy metals in natural waters: Applied monitoring and impact assessment. Springer-Verlag, New York.

Oladimeji, A.A., S.U. Qadri, G.K.H. Tam and A.S.W. DeFreitas. 1979. Metabolism of inorganic arsenic to organoarsenicals in rainbow trout. Ecotoxicology and Environmental Safety 3: 394-400.

Sorensen, EMB. 1976. Thermal effects of the accumulation of arsenic in green sunfish. Arch Environ. Contam. Toxicol. 4: 8-17.

Swanson, S.M. 1985. Food-chain transfer of U-series radionuclides in a northern Saskatchewan aquatic system. Health Physics 49(5): 747-770.

U.S. EPA 1993. Guidance for assessing chemical contaminant data for use in fish advisories. Environmental Protection Agency Report EPA 823-R-93-002.

Whicker, F.W. and V. and Schultz 1982 Radioecology: nuclear energy and the environment. CRC Press, Boca Raton, FL

Wood, C.M., WS Adams, GT Ankley, DR DiBona, SN Luoma, RC Playle, WC Stubblefield, HL Bergman, RJ Erickson, JS Mattice and CE Schlekat. 1997. Environmental toxicology of metals. Pp. 31-51 In Bergman, HL, Dorward-King EJ (eds.) Reassessment of metals criteria for aquatic life protection. SETAC Press, Pensacola, FL.

Appendix IV.2 MOE Laboratory Services Branch Method References for Fish Tissue Analysis

MOE LABORATORY SERVICES BRANCH (LSB) METHOD REFERENCES FOR FISH TISSUE ANALYSES

E3072
THE DETERMINATION OF HEAVY METALS IN BIOMATERIALS BY ATOMIC ABSORPTION SPECTROPHOTOMETRY (AAS)

E3416
THE DETERMINATION OF TRACE METALS IN FISH TISSUE BY ICP-MS

LSB Detection Limits

E3416 - Detection Limits (µg/L)(1999)

Element	DL
Al	0.500
Ni	0.075
Co	0.010
Cu	0.200
Zn	0.200
Ag	0.030
Pb	0.060
U	0.010
As	0.100

Appendix IV.3 Concentrations of Metals of Concern in Fish Samples and Graphs Not Included in Main Report

IV.3-1

Mean Fish Tissue Concentration of Metals the 1999 Sentinel Fish Sampling Program [ug/g-wet weight]

Parameter	Longnose Dace			Average	White Sucker								Average	Total Average
	F1	F2	F3		CL	ML	MR11	MR17	MR14	MR15	RL	SL		
Arsenic	0.094	0.11	1.08	0.41	0.034	0.39	0.56	0.24	0.31	0.12	0.070	0.50	0.27	0.31
Cobalt	0.32	0.052	0.36	0.24	0.024	0.12	0.14	0.062	0.097	0.040	0.027	0.055	0.070	0.11
Copper	0.79	0.65	1.15	0.86	0.55	0.63	0.83	1.42	0.73	0.76	0.54	0.60	0.76	0.78
Lead	0.014	0.0056	0.0052	0.0081	0.11	0.0070	0.012	0.023	0.012	0.0020	0.020	0.040	0.028	0.023
Nickel	0.29	0.25	0.42	0.32	0.25	0.24	0.20	0.22	0.32	0.30	0.18	0.25	0.25	0.26
Silver	0.0074	0.0077	0.041	0.018	0.0023	0.0030	0.0080	0.0061	0.0041	0.0027	0.0031	0.0025	0.0040	0.0077
Uranium	0.0014	0.00071	0.00071	0.00095	0.00067	0.00067	0.00073	0.0018	0.0015	0.00083	0.0011	0.0026	0.0012	0.0011

Average Sediment Grab Concentration of Metals in Moira Water Shed 1999 [ug/g-dry weight]

Parameter	Station									Grand Total
	BR	CL	ML	MR	RL	SK	SL	SR	YC	
Arsenic	4.7	1.34	158.49	232.27	3.014	2.3	34.6	2.2	3000	143.9
Cobalt	7.1	1.95	308.79	251.13	8.07	6.3	42.53	8.5	1600	162.0
Copper	6	5.25	58.14	52.75	21.57	6	15.73	19	3200	81
Lead	4	12.38	36.71	25.19	43.86	6	24.2	33.67	56	28
Nickel	8.5	3.39	225.86	201.76	11.8	9.3	31.39	17	1000	122
Silver		0.1	3.46	6.35	0.4	0.2	0.33	0.2	4	3
Uranium	0.37	0.41	1.10	0.87	0.91	1.23	1.24	1.39	19	1

Average Sediment Grab Concentration of Metals in Moira River 1999 [ug/g-dry weight]

Parameter	Moira River Station #																Grand Total
	MR-1	MR-10	MR-11	MR-12	MR-13	MR-14	MR-15	MR-16	MR-2	MR-3	MR-4	MR-5	MR-6	MR-7	MR-8	MR-9	
Arsenic	1.4	260	660	17	50	21	11	29	2.9	14	140	170	280	500	1300	260	232
Cobalt	5.6	740	1100	45	150	55	33	38	7.5	9	25	140	240	450	440	540	251
Copper	6	100	190	10	40	13	4	35	12	11	23	39	78	110	75	98	53
Lead	3	28	66	11	51	26	9	69	5	8	11	25	25	22	20	24	25
Nickel	9.2	470	680	24	73	34	14	26	15	13	33	77	250	550	520	440	202
Silver		11	19		0.6	0.2		0.2			0.5	10	4.6	6.3	6.5	11	6
Uranium	0.26	0.89	1.2	1.03	3.91	1.7	0.43	0.51	0.30	0.39	0.48	0.47	0.52	0.54	0.41	0.89	0.9

Concentration of Metals in Moira River and Tributaries [mg/L-wet weight]

PDESC	Year	UNITS	Station											
			Black R	Clare R	Deer Cr	ML	MR-1	MR-10	MR-11	MR-2	MR-5	MR-7	PC	Skootamatta R	SL
Arsenic	1999	mg/L	0.0005	0.00063	0.00075	0.020	0.0005	0.0041	0.00067	0.059	0.0047	0.0032		0.0005	0.0052
Cobalt	1999	mg/L	0.00031	0.00013	0.00038	0.0012	0.00040	0.00058	0.00030	0.0016	0.00037	0.00034	0.00033	0.00023	0.0005
Copper	1999	mg/L	0.00055	0.00094	0.0012	0.00044	0.00022	0.00030	0.00043	0.0012	0.00071	0.00031	0.00048	0.00054	0.0006
Lead	1999	mg/L	0.0011	0.0018	0.0026	0.0015	0.0032	0.0023	0.0027	0.0027	0.0019	0.0027	0.0039	0.0020	0.0026
Nickel	1999	mg/L	0.00031	0.00057	0.00048	0.0039	0.00087	0.0011	0.00020	0.0020	0.0024	0.00085	0.00068	0.00022	0.0025
Silver	1987	mg/L			0.0002										
Uranium	1991	mg/L	0.00024												

Bio-Accumulation Factor (BAF) for Fish Tissue Concentration of Metals in 1999 [Fish/Sediment]

Parameter	Longnose Dace			Average	White Sucker								Average	Total Average
	MR1	MR2	MR3		CL1	ML1	MR4	MR5	MR6	MR7	RL1	SL1		
Arsenic	0.020	0.011	0.023	0.018	0.0076	0.00074	0.0012	0.00042	0.00033	7.04E-05	0.0070	0.0041	0.0027	0.010
Cobalt	0.017	0.0021	0.012	0.010	0.0037	0.00011	0.0017	0.00013	0.00012	2.634E-05	0.00099	0.00039	0.00090	0.0056
Copper	0.04	0.016	0.031	0.029	0.031	0.0032	0.011	0.011	0.0028	0.0021	0.0075	0.011	0.010	0.019
Lead	0.0014	0.00034	0.00019	0.00063	0.0026	5.7E-05	0.00033	0.00028	0.00014	2.771E-05	0.00013	0.00049	0.00050	0.00057
Nickel	0.0093	0.0050	0.0096	0.0080	0.022	0.00032	0.0018	0.00087	0.00038	0.00017	0.0046	0.0024	0.0040	0.0060
Silver					0.0070	0.00026	0.0048	0.00018	0.00027	0.00013	0.0023	0.0023	0.0022	0.0022
Uranium	0.0017	0.00072	0.00054	0.00097	0.00049	0.00018	0.00046	0.0011	0.00085	0.00046	0.00035	0.00064	0.00057	0.00077

Sediment Moisture Content 70%

Bio-Accumulation Factor (BAF) for Fish Tissue Concentration of Metals in 1999 [Fish/Water]

Parameter	Longnose Dace			Average	White Sucker								Average	Total Average
	MR1	MR2	MR3		CL1	ML1	MR4	MR5	MR6	MR7	RL1	SL1		
Arsenic	189.00	1.81	18.41	69.74		19.72	9.50	4.07	5.34	2.01		90.52	21.86	45.80
Cobalt	800.83	33.20	967.87	600.63		97.87	88.78	40.01	62.32	25.36		119.90	72.37	336.50
Copper	3598.64	552.66	1612.50	1921.27		1435.61	700.71	1203.95	620.71	645.95		1017.75	937.44	1429.36
Lead	4.26	2.02	2.70	2.99		4.53	4.41	8.34	4.18	0.73		15.32	6.25	4.62
Nickel	329.52	121.19	174.30	208.34		60.98	98.64	109.02	155.95	148.08		101.37	112.34	180.34
Silver	37.14	38.71	202.75	92.87		15.10	40.02	30.33	20.72	13.73		12.64	22.09	57.48
Uranium	6.02	2.97	2.94	3.97		2.81	3.055	7.37	6.12	3.44		11.03	5.64	4.80

Moisture Content of Dace 0%
Moisture Content of Sucker 0%

Figure IV-1
Average (with Standard Error) of Lead Concentration in White Sucker Tissue Samples Taken at Each Location

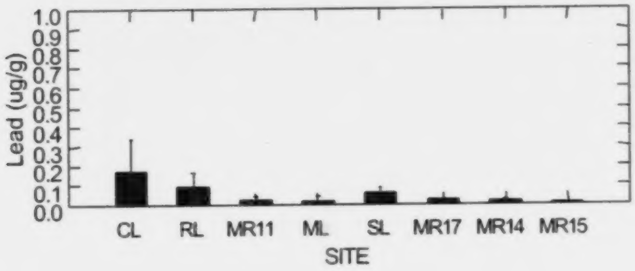


Figure IV-2
Average (with Standard Error) of Nickel Concentration in White Sucker Tissue Samples Taken at Each Location

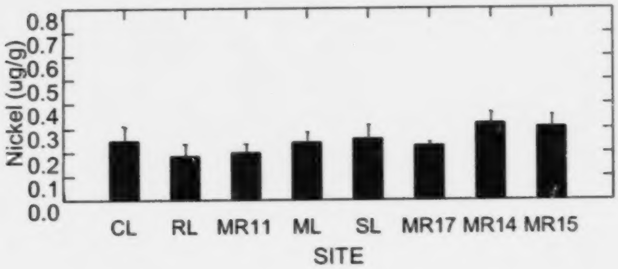


Figure IV-3
Average (with Standard Error) of Cobalt Concentration in Longnose Dace Tissue Samples Taken at Each Location

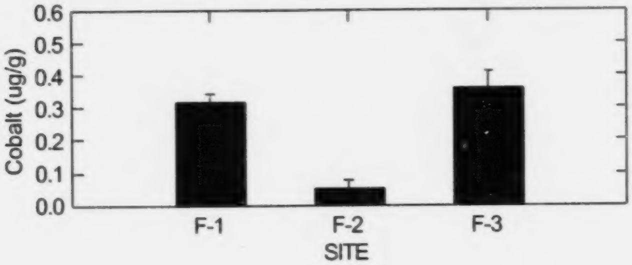


Figure IV-4
Average (with Standard Error) of Copper Concentration in Longnose Dace Tissue Samples Taken at Each Location

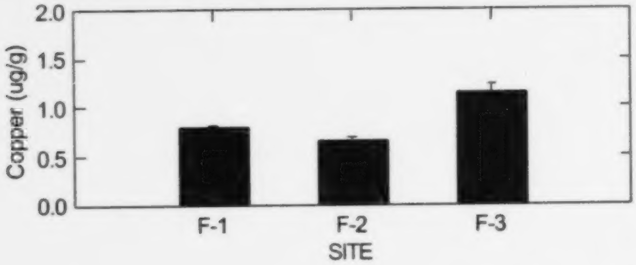


Figure IV-5
Average (with Standard Error) of Lead Concentration in Longnose Dace Tissue Samples Taken at Each Location

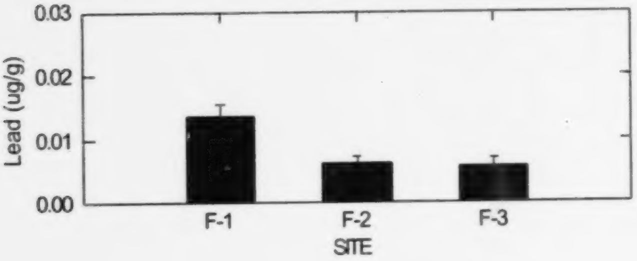
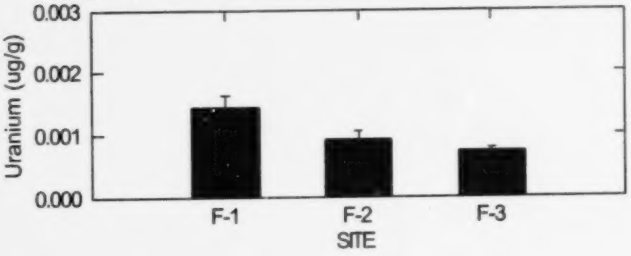


Figure IV-6
Average (with Standard Error) of Uranium Concentration in Longnose Dace Tissue Samples Taken at Each Location



Appendix IV.4 Analysis of Fish Metal Content Versus Size of Fish

Concentration of contaminants of concern in fish tissue (µg/g dry weight) plotted against white sucker length (mm) for exposed and reference sites; 1999 Sentinel Fish Sampling Program.

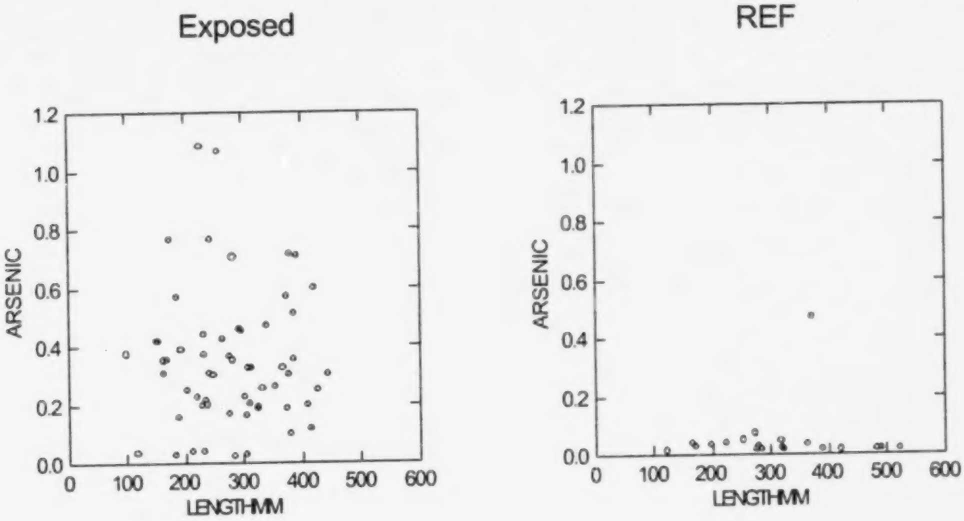
Exposed site indicates the pooling of data from the following sampling stations:

- Bend Bay
- HWY-37 / Moira River
- Latta
- Moira Lake
- Stoco Lake
- Thomasburg

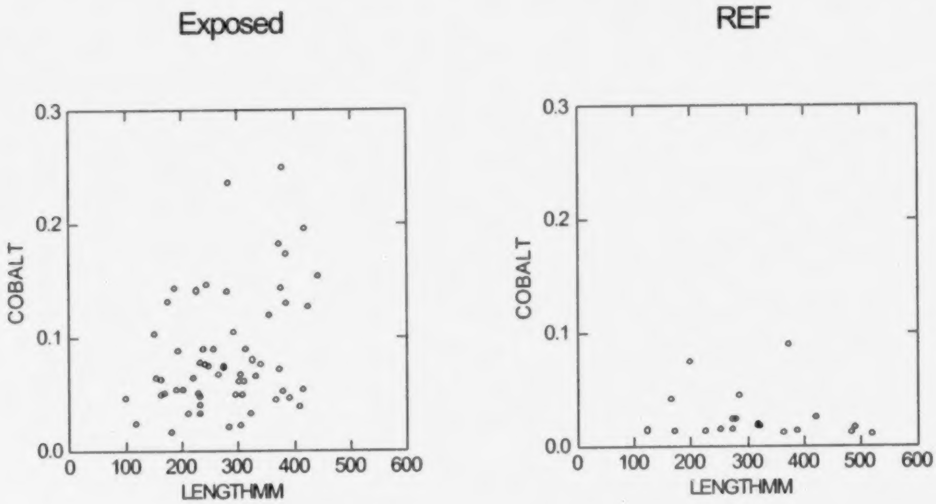
Reference site indicates the pooling of data from the following sampling stations:

- Consecon Lake
- Round Lake

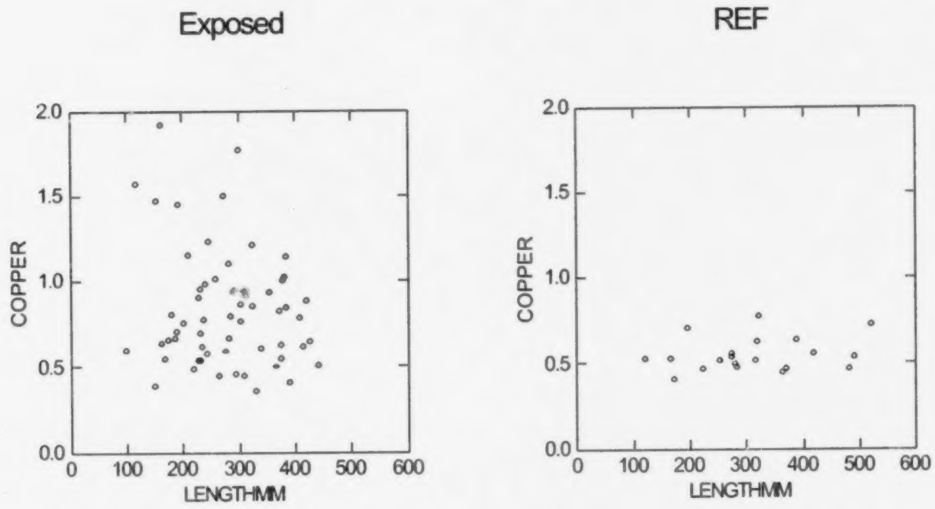
Concentration of Arsenic in White Sucker Tissue (µg/g dry weight) and Fork Length (mm) for Exposed and Reference Locations



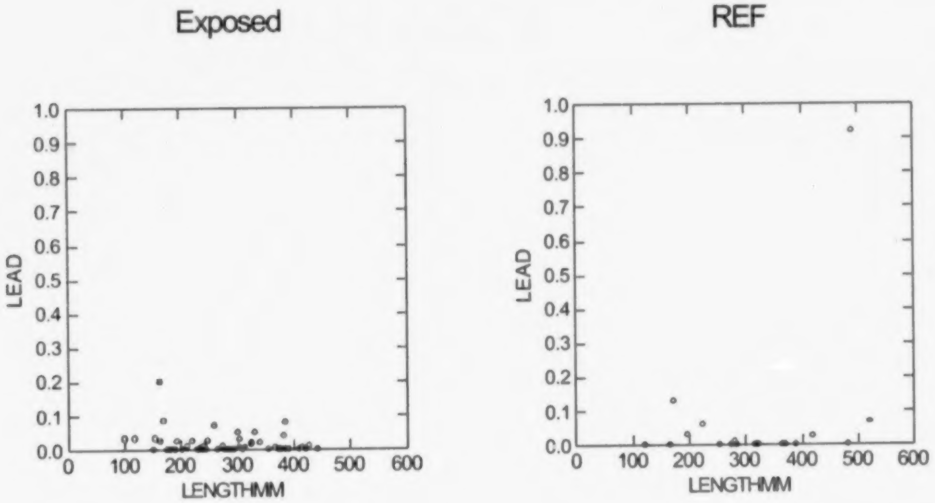
Concentration of Cobalt in White Sucker Tissue (µg/g dry weight) and Fork Length (mm) for Exposed and Reference Locations



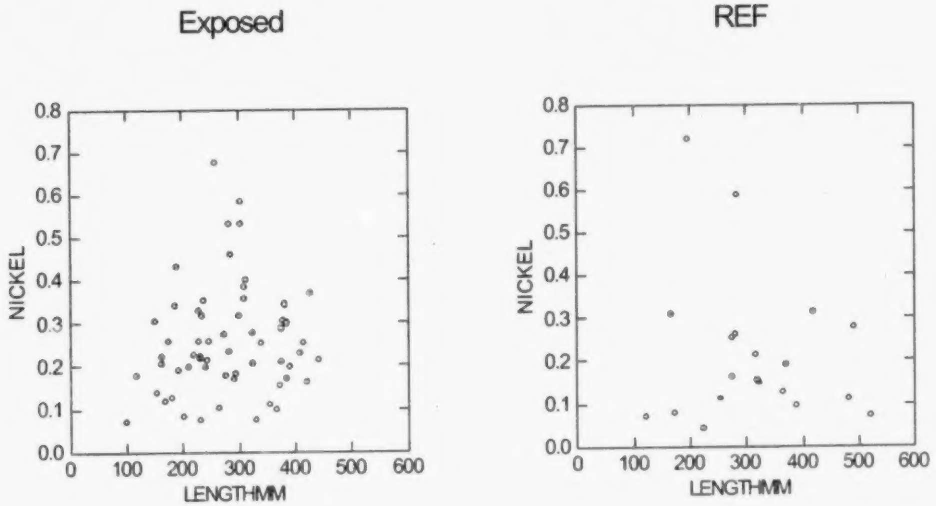
Concentration of Copper in White Sucker Tissue (µg/g dry weight) and Fork Length (mm) for Exposed and Reference Locations



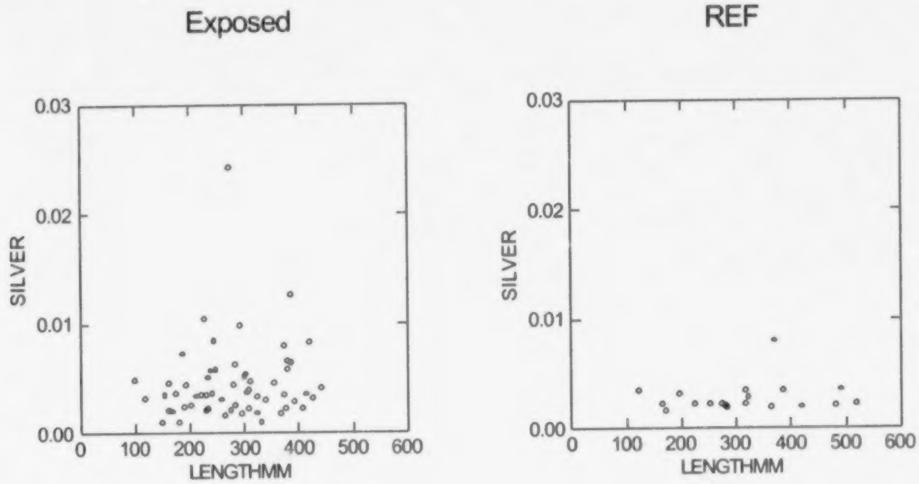
Concentration of Lead in White Sucker Tissue (µg/g dry weight) and Fork Length (mm) for Exposed and Reference Locations



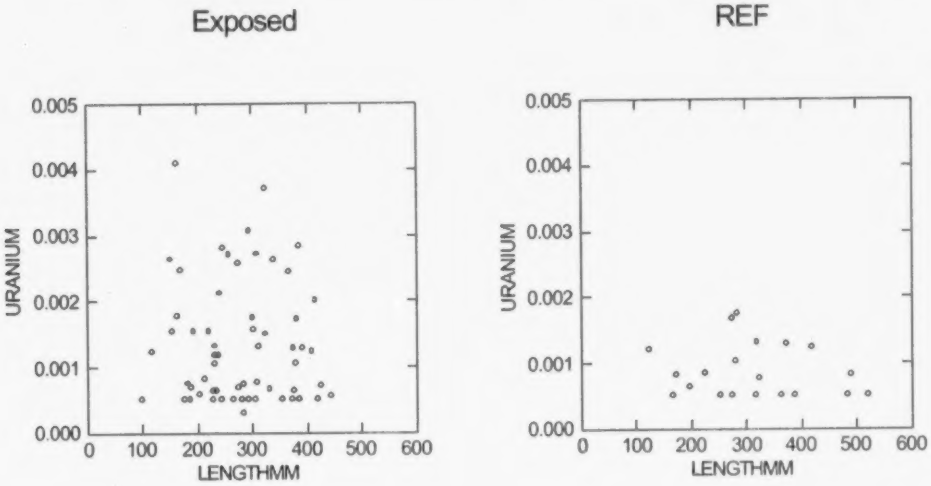
Concentration of Nickel in White Sucker Tissue (µg/g dry weight) and Fork Length (mm) for Exposed and Reference Locations



Concentration of Silver in White Sucker Tissue (µg/g dry weight) and Fork Length (mm) for Exposed and Reference Locations



Concentration of Uranium in White Sucker Tissue (µg/g dry weight) and Fork Length (mm) for Exposed and Reference Locations



Appendix IV.5 Golder Technical Procedure for Collection of Fish Samples for the Study of Metal Effects

GOLDER TECHNICAL PROCEDURES
Golder Technical Procedure 8.16-0 Fish Health Assessment – Methods

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Exhibit D Chain-of-Custody Form

1 PURPOSE

The purpose of this technical procedures document is to:

- describe sampling methods for fish health assessment;
- provide standardization of these methods amongst personnel, sites, sample times, and studies; and,
- document the standard fish health sampling methods employed by Golder Associates Ltd.

The following methods are covered in this technical procedure document:

- special precautions for samples taken for metal contaminant analysis;
- general sampling procedures for fish health assessment;
- sample packaging, preservation, labelling, and shipping procedures; and,
- field documentation.

2 APPLICABILITY

These technical procedures are applicable to all personnel involved in fish health surveys. **These procedures are to be used only at sites where there is potential exposure of fish to metals.** At other sites, where potential fish exposure to organic compounds, or mixtures of organics and metals are an issue, refer to TP 8.15 and 8.17, respectively. These technical procedures assume that fish have been captured according to methods outlined in TP 8.1-3 Fish Inventory Methods.

3 DEFINITIONS

3.1 Ageing Structures

Parts of the fish that are taken for ageing analyses. These structures contain bands (annuli) that delineate seasonal variation in growth; these bands can be counted to estimate age. Primary examples of these structures are scales, fin rays, otoliths, cleithra and opercula. The appropriate ageing structures to collect vary according to fish species and lifestage and include lethal and non-lethal sampling measures (Table 1).

3.2 Archive Samples

Extra samples which are taken and kept in storage for possible later analysis.

3.3 Bile

An alkaline secretion of the vertebrate liver, which is temporarily stored in the gall bladder. It is composed of organic salts, excretion products and bile pigment. It is responsible primarily for emulsifying fats in the small intestine.

3.4 Biomarker

Biomarker refers to a chemical, physiological or pathological measurement of exposure or effect in an individual organism from the laboratory or the field. Examples include levels of: liver detoxification enzymes (e.g. metallothionein); metabolized contaminants in bile; sex steroids in serum.

3.5 Chain-of-Custody Forms

Standardized forms used as a means of keeping close track of samples that are taken from the field and transported to laboratories for analysis. Whenever the samples are transported from the field, the custody is relinquished from the delivery person to the receiver by signatures on the forms. These forms substantially decrease the risk of losing samples because they provide a clear record of the chain of transport and handling of the samples.

3.6 Contaminants

A general term referring to any chemical compound added to a receiving environment in excess of natural concentrations. The term may include chemicals not generally regarded as "toxic", such as nutrients, colour and salts.

3.7 Electroshocking

The use of electricity to stun and capture fish. An electrical current is passed between electrodes placed in the water; this current causes passing fish (galvanotaxis) to be attracted toward the positive electrode (anode). Once fish pass close to the anode the current acts as a narcotic and stuns the fish (galvanonarcosis), allowing them to be easily netted. Once captured, the fish may be identified, weighed, measured, tagged and then returned to the water. Fish taken by electrofishing revive quickly when returned to the water. Effort is automatically recorded by the electrofishing unit as the number of seconds of active electrofishing (i.e. time current is applied to the water).

3.8 Fecundity

The most common measure of reproductive potential in fish. It is the total number of eggs in the ovary of a gravid female fish. Fecundity normally increases with the size of the female within a given species.

3.9 Gonads

Organs that are responsible for producing haploid reproductive cells in multicellular animals. In the male, these are the testes and in the female, the ovaries.

3.10 GSI

Gonad-Somatic Index. The proportion of reproductive tissue in the body of a fish. It is calculated by dividing the total weight of the gonad by the total body weight and multiplying the result by 100. It is used as an index of the proportion of growth allocated to reproductive tissues in relation to somatic growth.

3.11 LSI

Liver-Somatic Index. Ratio of liver versus total body weight. Expressed as a percentage of total body weight.

3.12 Lesions

Pathological change in body tissue.

3.13 Metallothionein

Metallothioneins (MT) are a group of proteins present in fish that are responsible for binding and maintenance of metals, including heavy metals. MTs are inducible, that is, exposure to metals causes increase MT production. Therefore, MT levels in fish tissue are a useful indicator of exposure to heavy metals.

3.14 Necrosis

The death of a tissue due to injury or disease.

3.15 Reference Site

A site used for comparison with a site exposed to the discharge being studied. Ideally, reference sites should be as similar as possible to the exposed site, but without the discharge.

3.16 Sampling Error

Sample inaccuracy caused by bias or imprecision in sampling; e.g., bias towards large fish because of the type of sampling gear. In statistics, sample error is expressed by the standard deviation, which expresses the variability of results around the mean.

3.17 Secondary Sex Characteristics

External sexual characteristics displayed by fish, particularly during spawning season. Examples are tubercles on fins or body coloration.

3.18 Sex Determination (Lethal)

Sex can be determined by examining the gonads during the internal examination. Ovaries appear whitish to greenish to orange and have a granular texture. Testes appear creamy white and have a smooth texture (Texas Water Commission, 1990).

3.19 Sex Determination (Non-Lethal)

For some species, sex may be determined from external secondary sexual characteristics, observable either during the spawning season (e.g. suckers - tubercles in males) or at any time of year (e.g. goldeye - anal fin morphology). For most fish species, sex can be determined during the spawning season by forcing extrusion of the sexual product (milt/roe)

3.20 Standard Deviation

A measure of the variability or spread of the measurements about the mean. It is calculated as the positive square root of the variance.

3.21 SWI

Specific Work Instructions

3.22 TDG

Transport of Dangerous Goods

3.23 WHMIS

Workplace Hazardous Materials Information System

4 REFERENCES AND SUGGESTED READING

Anderson, R.O. and S.J. Gutreuter. 1983. Length, Weight and Associated Structural Indices. In: Fisheries Techniques. L.A. Nielsen and D. Johnson (eds.). American Fisheries Society, Bethesda, MD. Pp. 283-300.

Carlander, K.D. 1969. Handbook of Freshwater Fishes of the United States and Canada. 3rd Ed. Iowa State University Press, Ames, I.A.

Environment Canada. 1993. Technical Guidance Document for Aquatic Environmental Effects Monitoring Related to Federal Fisheries Act Requirements. Department of Fisheries and Oceans. Ottawa, Ontario.

Environment Canada. 1995. Further Guidance for the Adult Fish Survey for Aquatic Environmental Effects Monitoring Related to Federal Fisheries Act Requirements. Department of Fisheries and Oceans. Ottawa, Ontario.

Hayes, M.L. 1983. Active Capture Techniques. In: Fisheries Techniques. L.A. Nielsen and D.L. Johnson (eds.). American Fisheries Society, Bethesda, M.D. pp. 123-146.

Jearld, A. 1983. Age determination. In: Fisheries Techniques. L.A. Nielsen and D. Johnson (eds.). American Fisheries Society, Bethesda, MD. Pp. 301-324.

MacKay, W.C., Ash, G.R., and H.J. Norris (eds.). 1990. Fish Ageing Methods for Alberta. R.L.&L. Environmental Services Ltd. in assoc. with Alberta Fish and Wildlife Div. and Univ. of Alberta, Edmonton. 113 p.

Puget Sound Estuary Program. 1990c (revised). Recommended Protocols for Fish Pathology Studies in Puget Sound. In: Recommended Protocols and Guidelines for Measuring Selected Environmental Variables in Puget Sound. Prepared by PTI Environmental Services, Bellevue, WA. Region 10, U.S. Environmental Protection Agency, Seattle, WA.

Rohif, F.J., H.R. Akcakaya and S.P Ferraro. 1991. Optimizing Composite Sampling Protocols. Contract 68-CO-0051. Prepared for the U.S. Environmental Protection Agency. Applied Biomathematics, Corvallis, OR.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Bulletin #184, Fisheries Research Board of Canada, Fisheries and Oceans, Ottawa, Ontario. 966 p.

Smith, R.L. 1985. Guidance on Sampling Aquatic Organisms for Tissue Analyses during FY 1986. Environmental Services Division, Region 3, U.S. Environmental Protection Agency, Philadelphia, PA.

Stober, Q.J. 1991. Guidelines for Fish Sampling and Tissue Preparation for Bioaccumulative Contaminants. Environmental Services Division, Region 4, U.S. Environmental Protection Agency, Athens, G.A.

Texas Water Commission. 1990. Texas Tissue Sampling Guidelines. Texas Water Commission, Austin, TX.

USEPA. 1993. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories; Volume 1: Fish Sampling and Analysis. United States Environmental Protection Agency. Office of Science and Technology and Office of Water. Washington, D.C.

WDNR (Wisconsin Department of Natural Resources). 1988. Fish Contaminant Monitoring Program -- Field and Laboratory Guidelines. Report No. 1005.1. Madison, WI.

5 DISCUSSION

5.1 General Safety

Refer to Golder Associates Ltd. Safety Manual for general safety procedures.

All solvents and preservatives required for field work must be packaged, labelled, shipped, and used according to WHMIS and TDG regulations.

All used "sharp" dissecting/sampling equipment (needles, scalpel blades, etc.) must be placed in a designated "sharps" disposal container.

5.2 Sampling Procedures for Fish Health Assessment

5.2.1 General Considerations

The procedures outlined here assume that fish have been captured according to methods outlined in TP 8.1-3, and that associated supporting receiving environment measurements have been recorded. These measurements may include: water temperature, pH, dissolved oxygen, conductivity, secchi reading and current weather conditions (e.g., cloud cover, air temperature, approximate wind speed, precipitation, etc.). Also, relevant data for fish population status assessment may be recorded according to TP 8.1-3. These data may include: species identification, weight (g), length (mm), life history staging (fry, juvenile, adult), sex (refer to Section 3.27) and sexual maturity (if possible), and presence of abnormal external pathology (e.g., fin erosion, ulcers, skeletal anomalies, neoplasms). A fish sample number may be assigned according to TP 8.1-3; and aging structures may be collected. Ageing materials to be collected for each fish species are summarized in Table 1 (MacKay et al. 1990).

Concerns regarding the effect of capture and holding stress on fish, particularly on sensitive physiological biomarkers, may require that fish are captured using specific techniques, such as electroshocking. Refer to specific work instructions (SWI) for instructions.

Prior to sampling for fish health, fish can be held temporarily in a live holding facility, such as a live well, holding pen, or tub. If necessary, fish can be marked at the time of capture using temporary tags (floy tags or fin clipping) for later identification during sampling.

For fish selected for biomarker processing, record time (24-hour clock) of capture. Large fish that are moribund or dead should be fully processed for biological data (sex maturity, internal pathology) unless time limits between capture and processing for specific parameters (e.g. histopathology) have been established.

The full set of procedures outlined in this document may not be required for a particular project. Always refer to Specific Work Instructions (SWI) for specific instructions.

Samples must not be allowed to thaw once frozen. Protect sample integrity by ensuring adequate dry ice levels in cooler and then take measures to expedite shipping to the analytical laboratory.

Ensure that histology samples are properly preserved in 10% neutral buffered formalin. In order for total preservation to take place, 10% neutral buffered formalin should be added so that there is a formalin to tissue ratio of 10 to 1. This is best accomplished by having one nalgene container dedicated to all the histology samples from one fish. Place all tissue cassettes for an individual fish into a single nalgene container, and fill the container with 10% neutral buffered formalin.

5.2.2 General Preparations for Sampling

All new personnel must read the technical procedures for Fish Inventory (TP 8.1-3), and Fish Health Assessment (TP 8.15-0, 8.16-0, or 8.17-0 - whichever is applicable). Personnel must understand the protocol for fish health assessment, have it demonstrated and then practice the procedures on at least 2 practice fish.

Battery operated balances are to be checked daily. Level balance at work area and check calibration using standard weights. A vial, weigh paper; anything that has been weighed on a calibrated lab balance may be used. Shield from wind if necessary.

All biomarker data are to be recorded in waterproof field notebooks, Biomarker forms (Exhibit A), External and Internal Examination forms (Exhibit B and C).

5.2.3 Special Precautions to Prevent Contamination of Samples Taken for Metals Analysis

Special care is required to minimize the chance of contaminating samples for metals analysis.

If you are collecting contaminant samples, use a fresh filleting knife and dissecting equipment for each fish. Fresh syringes must also be used for each bile and blood sample.

During the dissection process, take care that the tissues designated as metal samples are dissected on a washable plastic surface covered with a plastic sheet which is changed after each dissection. The fish is to be placed on the plastic dissection surface and kept there while the fillet for metals are taken. The fillet for metals must be placed in a labelled plastic bag. If other organs are also being taken for contaminants analysis (e.g. liver, kidney) special care will have to be taken to isolate the section of the organ to be used for metals and take it while still on the plastic and then carefully remove the other section of the organ without contacting the plastic.

All samples to be analyzed for metals must be placed in plastic packaging, not foil.

Stainless steel dissecting instruments are made predominantly of chromium and nickel. If these metals are not of concern (refer to SWI), the use of high-quality, corrosion-resistant stainless steel sample processing equipment is acceptable (USEPA 1993). Knives with titanium blades and PTFE handles are recommended for performing tissue resections (Lowenstien and Young 1986, USEPA 1993) but clean plastic handles can also be used. Following use, dirt and tissues should be removed from the instruments with distilled water before washing. For washing, utensils and containers should be cleaned thoroughly with a detergent solution, rinsed with tap water, soaked in acid, and then rinsed with metal-free water. Quartz, PTFE, glass, or plastic containers should be soaked in 50% HNO_3 for 12 to 24 hours at room temperature (USEPA 1993). Stainless steel parts may be cleaned as stated for glass or plastic, omitting the acid soaking step (Stober 1991, in USEPA 1993).

All dissecting equipment is to be wrapped in heavy plastic wrap during storage; and all dissecting equipment, sample containers, sample wrapping and wash equipment must be shipped and stored in clean waterproof containers with leak-proof lids.

5.2.4 Specific Steps Involved in Sampling for Fish Health Assessment

This section provides detailed step-by-step instructions for sampling for fish health assessment; these steps are summarized in the flow chart entitled "Protocol for fish health sampling at metals sites" (Figure 1). **Throughout these procedures, refer to specific work instructions (SWI) for project applicable procedures.**

1. Insure the dissection surface (i.e. cutting board) is covered in clean, heavy plastic wrap and that all instruments are clean and readily available to you. Check with the data recorder that all is in order before dissection begins (e.g. sample numbers, labels, dry ice supply, etc.).

2. Assign a biomarker number to fish based on instructions in Section 5.3

3. Put on a clean pair of non-chlorinated, non-powdered latex examination gloves.

4. The next step taken is governed by whether fish is alive or dead, and if dead, for how long. If fish is alive, fish will be processed for the full series of biomarkers and tissue sampling called for in the SWI; in this case proceed to step 5. If fish has been dead for less than 4 hours, proceed to step 8. If fish has been dead for more than 4 hours, then the fish must be rejected for histological sampling, but other measurements may be taken; in this case, proceed to step 8, but disregard instructions for collecting histological samples.

5. Select live fish from holding facility. Excessive handling of fish and stress is to be avoided. Ensure that the skin on the specimen has not been lacerated during sampling. If there has been laceration and loss of fluids, reject the specimen.

6. **Collect blood**: Specific blood sample collection and treatment methods will depend on the objectives of the work; refer to SWI for specific project applicable methods. Special requirements for serum steroid or other types of analyses may require that the fish be sampled within 1 hour of capture; refer to SWI for project specific instructions. Generally, blood collection must be done as quickly as possible, while minimizing stress to the fish. Blood collection proceeds as follows: place fish on dorsal surface into a foam block; withdraw blood from caudal vein using a clean, disposable syringe (size of syringe depends on size of fish - 1 to 5 ml may be suitable); label vial; and, place blood on wet ice for later preparation according to SWI.

7. Sacrifice the fish with a blow to the head. Note sacrifice time (24 hour clock) on log sheet.

8. Rinse the fish in ambient water to remove any foreign material from the external surface.

9. **Weigh and measure the fish** (to nearest gram and mm) and record results. Use fork length measurement except for species with no anal fin indentation (e.g. burbot) which should be measured for total length.

10. Place the fish on the cutting board.

11. **Collect gill samples for histopathology**: The gill tissues begin to degrade almost immediately after death, and must be removed as quickly as possible. Open the opercula and find the second gill arches on both sides of the fish. Cut out the second gill arch with a pair of scissors taking care to cut as close as possible to the dorsal and ventral insertions. Place the gill arches in a labelled histology cassette and immerse in a nalgene container filled with 10% neutral buffered formalin.

12. Examine the fish for external abnormalities and note on External Examination Form (Exhibit B).

13. **Collect fillet samples for metals analysis:** Remove two approximately 100 g fillets with a filleting knife that has been cleaned according to instructions outlined above. Remove skin

from fillets and ensure that no part of the fillet touches a surface that has not been covered in plastic. Place each fillet on a piece of plastic and record weight. Wrap each fillet in heavy plastic wrap, insert a label in the plastic (between wrapping) taking care not to touch the fillet. Securely tape a second label onto the outside of the plastic. Label one fillet per fish as an archive sample for possible later analysis. Place one fillet sample from each fish in a cooler with dry ice and store there until shipment to a lab. Place the archive fillet sample per fish in a cooler with dry ice clearly marked "archive samples or QC samples". Note: an alternative packaging for contaminant samples is a plastic bag.

14. **Collect skeletal muscle sample for histology**: After removing a fillet, locate the spinal cord just posterior to the dorsal fin. Remove a piece of skeletal muscle approximately 3 cm × 1 cm × 0.5 cm. Place the skeletal muscle in a labelled histology cassette and immerse in a nalgene container filled with 10% neutral buffered formalin.

15. Open body cavity by making an incision on the ventral surface of the body from a point immediately anterior to the anus toward the head to a point immediately posterior to the pelvic fins; cut intestinal tract at both ends; remove intestinal tract and set aside; remove gonads and set aside. Throughout this procedure and the procedures to follow, examine and record the internal condition of the fish, including the presence of parasites, on the Internal Examination Form. Preserve any abnormal tissues and parasites in 10% neutral, buffered formalin for later analysis. Ensure that histology samples contain both internal labels (waterproof paper and pencil) and external labels. Record tissues taken on the Internal Examination Form (Exhibit C) and in field notebook.

16. **Collect gall bladder:** Remove liver from body cavity, taking care not to puncture gall bladder. Identify the gall bladder, clamp bile duct using hemostat forceps, and remove gall bladder. Collect bile from gall bladder using a clean syringe, place in a cryovial, and freeze on dry ice. Alternately (depending of size of the organ), you may place the entire gall bladder intact into a cryovial and freeze on dry ice.

17. **Measure and record weight of entire liver.** Place liver onto a tared piece of plastic on scale, record weight.

18. **Collect sample for liver histology:** Make a longitudinal section through the middle of the liver and remove a strip of tissue approximately 3 cm X 1 cm X 0.5 cm. Place the sample into a tissue cassette; and preserve in 10% neutral buffered formalin in a nalgene container. For histology samples, the liver tissue should originate from a portion of the liver away from the bile duct.

19. **Collect sample for liver metallothionein analysis:** Collect an approximately 1 gm. sample of liver for metallothionein analysis. Record the exact weight, wrap the sample in plastic wrap with internal (placed between wrappings, not touching the sample), and external labels, and freeze on dry ice.

20. **Collect sample for liver metal contaminant analysis:** Take the remainder of the liver, weigh it, and wrap in heavy plastic wrap for contaminants analysis. Insert label in the plastic (between wrapping) taking care not to touch the tissue; and securely tape a label onto the outside of the plastic. Freeze the sample on dry ice.

21. **Collect sample for spleen histology:** The spleen is a dark purple or wine coloured organ at the distal end of the intestines. It is usually housed in a thin, clear mesentery which is

sometimes surrounded in adipose tissue. Remove the spleen in its entirety and place it in a tissue cassette and preserve in 10% neutral buffered formalin inside a nalgene container.

22. **Remove and record weight of entire kidney.** The kidney is difficult to remove without disrupting the integrity of the organ; usually, the organ has to be scraped from the fish. **However, histological analysis must be performed on intact undisturbed tissue.** To sample the kidney, perform the following steps: place a piece of clean plastic on the scale, and place a tissue cassette onto the plastic; tare the scale; using a scalpel, obtain two 1 cm thick portions of kidney (one near anterior end, one near posterior end) for histological analysis, place these portions into the cassette on the scale; remove the remainder of the kidney from the fish by scraping with a scalpel, placing the pieces of tissue next to the histological samples on the scale; record total kidney weight.

23. **Collect sample for kidney histology:** Preserve the histological samples previously placed in the tissue cassette in 10% neutral buffered formalin in a nalgene container.

24. **Collect sample for kidney metal contaminant analysis:** Wrap the remaining kidney tissue in heavy plastic wrap for contaminants analysis. Insert label in the plastic (between wrapping) taking care not to touch the tissue; and securely tape a label onto the outside of the plastic. Freeze the sample on dry ice.

25. **Collect sample for gonad histology:** Examine gonads, remove and weigh to nearest 0.1 g. Note sex and assign maturity rating (refer to Table 2 for maturity codes). Make a cross-sectional cut through the middle of the organ after weighing and determining state of maturity. Take the cross-section of testes or ovary and place it in a tissue cassette and preserve in 10% neutral buffered formalin inside a nalgene container.

26. **Collect samples for fecundity and egg diameter determination (perform this step only if fish is a pre-spawning female):** Remove approximately 1 gram of eggs from the midregion of the ovary and place them in round histology cassettes that are lined with foil. Tare the balance to the weight of any empty cassette and then weigh the samples. Label the cassette. A minimum of 50% of the total sample size per species per site must have fresh measurements of egg diameter. Measure 30 individual fresh eggs/female using a micrometer for egg diameter. Record, label and store each egg individually in a histology cassette with 10% neutral, buffered formalin. After the minimum sample size for fresh measurements has been reached, store 30 eggs/female together in a histology cassette with 10% neutral, buffered formalin for analysis at the lab. At the lab, the individual eggs measured fresh in the field will be remeasured and calculated for % shrinkage. The % shrinkage will be used to correct measurement of the samples that were not measured fresh in the field. Volumetric determinations of egg size are made by counting 100 eggs and placing in a graduated cylinder with a pre-measured volume of water. Measure the new volume after the eggs have been added and record. Eg. Pre-volume = 5 ml. Volume with eggs = 5.5 ml. Volume of eggs = 0.5 ml. Precision of volumetric measurements will be dependent upon the graduated cylinder used. NOTE: The precision required for volumetric measurements of egg size in Environmental Effects Monitoring studies is ± 1%. (E.g. if a 10-ml cylinder is used, measurements are expected to be precise to 0.1 ml. This may not be achievable with 100 very small eggs. If not achievable, make note in the field notes and record the actual precision - e.g. 0.5 ml).

27. **Collect sample for heart histology:** Cut away the pectoral girdle that protects the heart. Grasp the anterior portion of the heart, pull caudally and very gently separate the connection

to the ventral aorta. The heart can be pulled far enough out of the body to expose and sever the sinus using a scalpel. For histology samples, make a sagittal cut through the heart, place in a tissue cassette and preserve in 10% neutral buffered formalin inside a nalgene container.

28. **Collect sample for thyroid histology:** Cut away the ventral insertions of the gill arches, anterior to the heart. The isthmus of tissue in which the gill arches insert contains the thyroid gland although there is no obvious structure. Cut out this triangle of and place it in a tissue cassette and preserve in 10% neutral buffered formalin inside a nalgene container.

29. **Open and examine intestinal tract:** Observe and record qualitative stomach contents on internal examination form. Qualitative measurement of stomach contents is to be done by estimating the % of total volume of contents taken up by each food item. Be as specific as possible. For example, mayflies, stoneflies, caddisflies, water boatmen, water striders, beetles, not just "insects". Include % sediment or detritus and % plant material. Identify fish to species if possible, e.g., longnose sucker. Identify amphibian, bird or mammal prey as accurately as possible. If stomach contents are to be retained (refer to SWI), then place the stomach contents into a prelabelled whirlpak bag, and preserve by adding 10% neutral buffered formalin.

30. **Collect ageing structures:** Collect two different ageing structure materials (i.e., scales, pectoral fin ray, otoliths) as per species requirements in Table 1, unless otherwise specified in the Specific Work Instructions. Place ageing materials in an "ageing materials" envelope and label.

31. Discard the remains of the specimen into a sealed bag for later disposal in an appropriate manner (e.g. temporary storage in a freezer, or disposal at a landfill). Discard latex gloves.

32. Rinse off cutting board with ambient water. Put on a clean pair of latex gloves and place a fresh piece of washed foil on the board. Proceed to the next fish.

Once all samples have been taken from one site, ensure adequate dry ice levels in the cooler, attach a Chain-of-Custody (Exhibit D) to the inside lid of the cooler and then seal the cooler using duct tape. Do not mix samples from different sites in one cooler.

5.3 Assigning Fish Sample Numbers

All fish that are selected for fish health surveys are to be given an individual biomarker number. This is in addition to the fish number assigned at the time of capture. The biomarker number is to be recorded on all individual sample labels. The biomarker number is a unique number which identifies the fish by project, species type, site, season and year.

The following format is to be used for biomarker numbering:

e.g.,

WLD	95	P	2A	LNSC	013
Project	Year	Season	Site	Species	Fish No.

Project - a unique 3 character code relating to the project.
Year - use the last two numbers of the year e.g., 1986 = 86.
Season - a one character code relating to season.
P - Spring

U - Summer
F - Fall
W - Winter

Site - a one or two alphanumeric code relating to the site the sample was caught.

Species - a four character abbreviation for species, based on the following rules (MacKay et al. 1990):

a) use a four letter base abbreviation
b) for a one word name - use the first four letters
   e.g., GOLD for goldeye
c) two word names - use the first letter in each word plus the next consonant in each word
   e.g., ARGR for Arctic grayling,
   LKWH for lake whitefish, and,
   WHSC for white sucker
d) three word names - use the first letter in the first two words and the first letter and next consonant in the last word
   e.g., NRDC for northern redbelly dace

Fish No. - a three digit consecutive number. Individual numbering scheme for each species are to be used.

This labelling scheme may be superseded by labelling requirements specific to a project. However, a special labelling scheme may only be used at the authorization of the project manager and QA officer.

5.4 Instructions for Preparing a Composite Tissue Sample

All fish fillet samples for each composite will be placed in a labelled bag. The bag containing the samples to be composited will be labelled in indelible ink with the following information:

- name of the composite
- type of sample (i.e. bile, fillet etc.)
- project number
- name of the collecting company (i.e. Golder)
- analysis requested

Upon arrival at the laboratory all samples should be kept in the labelled bag and returned to it upon completion of preparation of the composite.

For fish fillets the following procedure should be used to prepare the composite:

- unwrap the individual samples that are to form one composite
- take a portion of fillet from each individual sample to use in the composite
- make sure to retain a portion of each individual sample and rewrap it
- the remaining portion of each individual sample should be returned to the labelled composite bag and archived (frozen to -25° C)

For bile samples the following procedure should be used to prepare the composite:

- take a small amount of bile from each cryovial that is to form part of the composite
- if possible, leave some of the bile in each cryovial to be archived for future analysis. In some circumstances when the volume of bile is small (< 0.1 ml), the whole sample may have to be used
- the remaining portion of each individual sample should be returned to the labelled composite bag and archived (frozen to -25° C)

For serum samples the following procedure should be used to prepare the composite:

- take a small amount of serum from each cryovial that is to form part of the composite
- leave some of the serum in each cryovial to be archived for future analysis
- each remaining portion of the individual samples should be returned to the labelled composite bag and archived (frozen to -25° C)

5.5 Sample Identification Label

The use of pre-printed labels is strongly encouraged.

5.5.1 Labelling for Individual Samples for Contaminant Analysis

Each label must be completed in indelible ink for each sample. For contaminant samples, the following information must be included on the label:
Project number
Collecting Agency or Firm-Golder
Biomarker number
Sampling date/time (24 hour clock)
Sample type: F = fillet, W = whole, ungutted, L = liver, B = bile, G = gonad, S = stomach, K = kidney.
Time-frame for analysis - immediate or archive

A completed sample identification label must be taped securely onto each foil-wrapped or bagged sample.

5.5.2 Labelling Composite Samples for Contaminant Analysis

Each label must be completed in indelible ink for each sample. For contaminant samples, the following information must be included on the label:

Project number
Collecting agency or firm
Sampling date/time (24 hour clock)
Sample Site
Sampler (name and signature)
Composite number
Species abbreviation
Sample type: F = fillet, W = whole, ungutted, L = liver, B = bile, G = gonad, S = stomach, K = kidney.
Chemical analysis requested - or refer to an accompanying Chain-of-Custody Form or Analysis Request Form

Time-frame for analysis - immediate or archive

A completed sample identification label must be taped securely onto each wrapped or bagged sample. An additional label identifying the composite sample must be placed on each plastic bag containing the wrapped or bagged samples. The same type of label may also be used for archive samples; simply indicate on the label that the samples are to be archived.

5.5.3 Labelling for Liver Metallothionein, Blood and Bile Samples

Each label must be completed in indelible ink for each sample; and, the following information must be included on the label:

Biomarker number
Sampling date/time (24 hour clock)

Then place a label on outside of the dewar, bag or cooler containing several bile, blood or liver metallothionein samples and including the following information on the label:

Project number
Collecting agency or firm
Sampler (name)
Time frame for analysis - immediate or archive
General sample type (e.g., bile, liver, etc.)

5.5.4 Labelling for Histology and Egg Samples

Each label must be completed in indelible ink for each sample. For histological and egg samples, the following information must be included on the label:

Project number
Sampling date/time (24 hour clock)
Biomarker number
Tissue type:
O = ovary
L = liver
H = heart
G = gill
ST = stomach
F = fin
T = testes
S = spleen
K = kidney
I = intestine
SK = skin
AB = air bladder

An additional label must be placed on the jar or plastic bag identifying the several cassettes or jars of preserved specimens contained within. The label must include the following:

Project number
Collecting agency or firm
Time frame for analysis - immediate or archive
General sample type (e.g., eggs for fecundity, histology samples)

5.6 Documentation

5.6.1 Field Record Keeping

For proper interpretation of field survey results, thorough documentation of all field sample collection and processing activities is required. All logbooks should be perfect-bound and waterproof, forms should be preprinted on waterproof paper, and only indelible ink and pencil (if form or paper is wet) should be used.

To document field activities, sample identification labels, field logbooks, Biomarker Forms (Exhibit A), External (Exhibit B) and Internal (Exhibit C) Examination Forms, and Chain-of-Custody forms (Exhibit D) should be used, in addition to forms described for fish capture records (see TP 8.1-3). This will serve as an overall "Chain-of-Custody", documenting all field samples and field events beginning with sample collection through biomarker processing and preservation and shipment to the laboratory.

5.6.2 Chain-of-Custody Form

Sample possession and proper handling of samples must be traceable from the time of sample collection, through laboratory and data analysis. A Golder Chain-of-Custody form must be completed and signed in indelible ink for each shipping container (e.g. ice cooler) used. Two copies of the Chain-of-Custody form must be sealed in a plastic bag and taped to the outside cover of the cooler. Ensure that the carrier responsible for delivering the samples also signs and dates all Chain-of-Custody forms.

5.6.3 Field Records and Logbook

All pertinent information on field activities and sampling efforts must be recorded in an appropriate (i.e., waterproof) bound logbook. The field crew leader is responsible for ensuring that sufficient detail is recorded in the logbook. The logbook must be complete enough to enable someone unfamiliar with the project to completely reconstruct field activity without relying on the memory of the field crew. All entries must be made in indelible ink, with each page numbered, signed and dated by the author, and a line drawn through the remainder of any partly used page. All corrections are made by a single-line cross-out of the error, entering the correct information, dating and initialing the change. Upon return to the office, all field notes must be photocopied and placed in the appropriate project files.

Entries in the field logbook must include:

- Purpose of proposed sampling effort.
- Date and time (24 hour clock) of sampling.
- Names of field crew leader and team members.
- Description of each sampling site, including information on any photographs that may be taken.
- Location of each sampling site, name and number, applicable navigational coordinates, waterbody name/segment number.
- Details of sampling method and effort, particularly deviations from Specific Work Instructions.
- Clear identification of site names and sample numbers.
- Field observations.

- Field measurements taken (e.g., pH, temperature, flow, dissolved oxygen, secchi, weather conditions).
- Sample shipping information.

The field logbook should also be used to document any additional information on sample collection activities, hydrologic conditions, boat or equipment operations, or any unusual activities observed or problems encountered that would be useful to the project manager when evaluating the quality of the monitoring data.

A biomarker logbook should also be kept. All pertinent information on fish biomarkers must be recorded in an appropriate (i.e., waterproof) bound logbook. The field crew leader is responsible for ensuring that sufficient detail is recorded in the logbook. The logbook must be complete enough to enable someone unfamiliar with the project to completely reconstruct fish biomarker field activity without relying on the memory of the field crew. All entries must be made in indelible ink, with each page numbered, signed and dated by the author, and a line drawn through the remainder of any partly used page. All corrections are made by a single-line cross-out of the error, entering the correct information, dating and initialing the change. Upon return to the office, all field logbooks and notes must be photocopied and placed in the appropriate project files.

Entries in the fish biomarker field logbook must include:

- Date and time (24 hour clock) of sampling.
- Names of field crew leader and team members.
- Site name and number.
- Secchi, water temperature, conductivity,
- Fish number and Biomarker number.
- Capture time/sacrifice time (24 hour clock)
- Length/ Total Weight.
- Sex and stage
- Liver: total weight, sample weights, sample time (24 hour clock), canister storage number, colour
- Fillet: sample weights
- Bile: colour, volume, canister storage number
- Gonads: total weight (testes or ovaries), egg weights, total fecundity count
- Abnormal tissues collected and preserved
- Ageing structures collected

Biomarker Forms, Catch Records, Fish Sample Records, External/Internal Examination Forms and Photo-Log Sheets are to be filled out, dated and signed. All forms should be cross-referenced to the appropriate field record via the fish number and/or composite number.

5.7 Change of Procedures

Variations from the established procedure requirements may be necessary due to unique circumstances in the field. All variations from established procedures shall be documented on Procedure Alteration Checklists (Exhibit G) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize the individual Field Crew Members to initiate variations as necessary. If practical, the request for variations shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented at the direction of the Field Biologist, provided that the Project Manager is notified of the variation within 24 hours of implementation and the Procedure Alteration Checklist is forwarded to the Project Manager and the QA Manager for review within 2 working days of implementation. If the variation is unacceptable to either reviewer, the activity shall be repeated or action shall be taken as indicated in the Comments section of the checklist.

All completed Procedure Alterations Checklists shall be maintained in project records.

5.8 Shipping of Samples

Samples are to be shipped by the fastest possible means to the analytical laboratory. The primary QA consideration in shipping samples is protecting sample integrity. Preserve sample integrity by ensuring adequate ice levels in coolers before shipment to laboratory. Coolers are to remain sealed throughout shipment. Weigh-bill numbers are to be noted on the copies of the Chain-of-Custody form retained after sealing the coolers. Each transfer of custody is to be noted and signed for. The coolers should be labelled as Perishable/Keep Cold/Time-Sensitive. Clearly indicate the analytical laboratory address as well as a Golder contact person and phone number. The crew leader is to telephone the processing laboratory and inform them of the upcoming delivery. The crew leader is also required to phone the processing laboratory to confirm arrival of the shipment and that analysis instructions are clear.

6 RESPONSIBILITY

All aquatic field crew members engaged in conducting fish inventories or fish biomarking studies are responsible for compliance with this procedure.

7 EQUIPMENT AND MATERIALS

7.1 General Supplies

First aid kit (including emergency phone numbers of local hospitals, family contacts for each crew member)
Topographical maps of sampling sites
Flagging material
Tool box
Fish tubs

7.2 Record Keeping

Field logbook (perfect-bound, waterproof)
Labels
Chain-of-Custody forms
Fish Sample Records
Unique Catch Records (boat, backpack, gillnet, seine net, etc.)
Indelible pens
Pencils
Applicable MSDS sheets and TGD placards

7.3 Biomarking Equipment (to be stored in waterproof, sealable equipment containers)

Specific Work Instructions
20 Litre pails for transfer and holding of fish
Fish measuring board (metric)
Balance (metric), calibration weights, balance levels and 9 volt batteries
Stainless steel forceps
Stainless steel filleting knives
Stainless steel dissecting scissors
Stainless steel scalpels
Stainless steel scalpel blades
Centrifuge (if taking blood samples)
Small whirlpacks
Nalgene bottles for histology samples
Histology cassettes
Hemostats for clamping off gall bladder
5 ml Cryovials
Blood tubes
Tube rack
Paper towels
0.15 M KCl
Non-chlorinated, non-powdered latex surgical gloves
Plastic wrap
10 ml syringe
18 g needle
5 ml syringe
27 g needle
Pipettes (if taking blood smears or serum samples)
Pipette Bulbs
Goggles
Gloves
"Sharps" disposal containers
Wash-tubs for field-washing of dissecting equipment
Detergent solution
Metal-free water
HNO_3
Distilled water
Used washing solution containers
Plastic cutting boards (washable)
Fish bonker
Folding tables (for biomarking stations)
Biomarker tent
Teflon wash bottle with distilled water
Medical tape
String
Several sizes of plastic bags including garbage bags
Cage material for holding fish in situ, if live-wells or fish tubs not available or too small

7.4 Sample Preservation and Shipping Supplies

Ice (wet ice and/or dry ice)
10% neutral buffered formalin
0.15% KCl
Scale envelopes
Ice chests
Duct tape
Clear shipping tape for Chain-of-Custody forms
Pre-printed labels

TABLE 1:
RECOMMENDED FISH AGEING STRUCTURES (FROM MACKAY ET AL. 1990).

SPECIES	AGEING STRUCTURE (most preferred structure in bold)			
	LETHAL		NON-LETHAL	
	Preferred	Secondary	Preferred	Secondary
lake sturgeon	otoliths	none	first pectoral fin ray[A]	none
Arctic grayling	sagittal otoliths	none	scales[B]	pectoral fin rays
cisco	sagittal otoliths	none	scales[B] (if fast growing)	none
lake whitefish	sagittal otoliths	undetermined	scales[B] (if fast growing)	pelvic fin rays
mountain whitefish	sagittal otoliths	none	scales[C]	undetermined
lake trout	sagittal otoliths	none	first three pelvic fin rays[A]	scales (for immature fish)
bull trout	sagittal otoliths	none	none (scales not suitable)	none
brook trout	sagittal otoliths	none	scales[C] (if < 3 yrs. old)	none
brown trout	sagittal otoliths	none	scales[D] (if < 3 yrs. old)	none
rainbow trout	sagittal otoliths	none	scales[E] (if fast growing)	none
cutthroat trout	sagittal otoliths	none	scales (unreliable)	none
northern pike	cleithrum (freeze)	opercular bones and vertebrae	first three pelvic fin rays[A]	scales[D] (fish up to 3 yrs. old)
goldeye	operculum	none	first three pelvic fin rays[A]	scales[C] (fish up to 5 yrs.)
mooneye	operculum	none	first three pelvic fin rays[A]	scales[C] (fish up to 5 yrs.)
yellow perch	opercular bone	none	pelvic spine and first two fin rays[A]	two anal spines[A]
walleye	opercular bones	otoliths	pelvic spine and first two fin rays[A]	dorsal spine
sauger	opercular bones	otoliths	pelvic spine and first two fin rays[A]	dorsal spine
burbot	sagittal otoliths	none	none	none
suckers spp.	none	none	pectoral fin rays[A]	scales (if <5 yrs.)
trout-perch	otoliths	none	none	none
sculpin spp.	otoliths	none	length-freq. analysis	none
cyprinids	otoliths	none	scales	length-freq. analysis
flathead chub	otoliths	none	pectoral fin ray[A]	scales
sticklebacks	otoliths	none	length-freq. analysis	none

[A] proximal end

[B] collect 10-15 scales from the left side between the front edge of the dorsal fin and the lateral line

[C] collected between the dorsal fin and the lateral line

[D] collected from above the lateral line just posterior to the dorsal fin

[E] collected from immediately dorsal to the lateral line, between the posterior edge of the dorsal fin and origin of the anal fin

TABLE 2:

MATURITY CODES AND DEFINITIONS

UNKNOWN (UN): This category is used when state-of-maturity cannot be determined. This will most often occur for fish which have only been examined externally, where no examination of the gonads has been conducted. It may also be used following internal examination of the gonads when the observer cannot definitely determine the maturity of the fish. The gonads have been examined but the observer is unsure which maturity category to use, or the conditions of the gonads do not appear to match any of the maturity categories. If this is the case, record a complete description of the gonads and, if possible, collect a sample for microscopic examination.

IMMATURE (IM): This category is for immature fish (fry or juvenile life stages); defined as fish which have never spawned before and will not spawn in the coming spawning season. The gonads will be undeveloped and will be small and largely transparent. They will be string-like organs situated on the dorsal surface of the body cavity (dorsal to other internal organs) and will lie close under the vertebral column. In very young or small fish, determination of sex from examination of the immature gonads may be difficult or impossible.

Male: The testes will typically be smooth in texture and yellow, pink or white in colour. In suckers and percids, immature male testes can be identified by the position of the testicular artery. The artery is usually totally or partially imbedded in the organ.

Female: The ovaries will typically have a granular texture and will be yellow or pink in colour. In suckers and percids, immature female ovaries can be identified by the position of the ovarian artery. The artery is usually completely outside the organ, resting on top of the surface tissue and attached with connective tissue.

MATURING (MA): A maturing fish is a fish which has not spawned before but will spawn in the coming spawning season. This category refers to a fish whose gonads are developing for the first time. Fish in the maturing category are, for the first time, considered adult fish as they are hormonally similar to sexually mature individuals. Since the gonads are developing for the first time, development may not be complete at the time the fish is examined. The gonads may be developed (enlarged and showing sperm or egg development) primarily at the anterior end. The posterior end of the gonad may still be undeveloped and appear thinner (similar to an immature gonad). This category can be difficult to interpret in the field, being difficult to tell from the *Green* category, and examination of the gonads by microscope may be required. In general, the gonads of a maturing fish will be smaller than those for a *Green* fish.

Male: In the field, maturing testes will be smaller and paler than those of fully developed males but considerably larger than immature testes. If unsure, take a sample for histological analysis and designate the fish as *Green* (GN).

Female: In the field, maturing ovaries will be smaller and paler than those of fully developed females but considerably larger than immature ovaries. If unsure, take a sample for histological analysis and designate the fish as *Green* (GN).

SEASONAL DEVELOPMENT (SD): Fish in this category are sexually mature adults which have spawned in one or more previous spawning seasons and will spawn in the coming spawning season. The gonads are undergoing their seasonal development following the last spawning season. This is the longest of the sexually mature stages as it extends from just after the post-spawning period until the next pre-spawning period, as the fish utilizes its resources to produce new gametes. For spring spawning fish (e.g. walleye, northern pike, longnose sucker, rainbow trout, etc.), this category would last from late May to early April of the next year. For fall spawning fish (e.g. lake whitefish, mountain whitefish, bull trout, brook trout, etc.) this category would last from the end of the fall spawning season one year (September to November) through to the fall of the next year. However, for most fish, gonadal development occurs primarily during the growing season with only limited gonadal development during the winter months.

Male: The testes will vary greatly in size and colour within this category depending on the time of year the fish is examined. Early in development (i.e. after the post-spawning period), the testes will be small and yellow to light orange in colour. By early fall (i.e. after the primary gonad development period in the summer), they will have grown to nearly mature size and be white in colour. At this point, the testes will be large and distinct. Note: Suckers have a black coloured testicular membrane which may mask the white colour of the testes.

Female: The ovaries will vary greatly in size and colour within this category depending on the time of year they are sampled. Early in development (i.e. after the post-spawning period), the ovaries will be small and yellow to light orange in colour. Developing oocytes will be small and dark orange in colour and will give the ovary a granular appearance. By early fall (i.e. after the primary gonad development period in the summer), the ovaries will have grown considerably to nearly mature size and be bright yellow to orange in colour. The individual eggs will be readily apparent.

PRE-SPAWNING (PR): Fish in this category are sexually mature adults which have spawned in one or more previous spawning seasons and will spawn in the coming spawning season. The *Pre-spawning* category follows right after the *Seasonal Development* category, with respect to both time and stage of gonadal development, and occurs when the gonads have completed their seasonal development prior to the spawning season. This is a short term condition which extends from time the gonads are fully developed until the start of spawning activity.

Male: Externally the abdomen will be slightly distended. Semen can sometimes be extruded with pressure to the abdomen. If this is the case, small amounts of loose semen will be extruded followed by more viscous semen if pressure is re-applied. Internally, the testes will be large and white and will fill much of the body cavity. Pre-spawning condition can also be inferred by the capture location of the male. Males will usually only enter spawning condition once they are on the spawning grounds and around mature females. Thus a male caught away from the spawning grounds as the spawning season approaches is most likely still in pre-spawning condition, even if some sexual products can be extruded. Note: Semen can be extruded from sexually mature males as early as February in spring spawning species.

Female: Externally the abdomen will be noticeably distended. Sometimes a few eggs can be extruded with strong pressure to the abdomen. Care must be taken when applying pressure as the eggs are difficult to extrude and injury to the female can occur. The abdomen will feel tight and hard. Internally, the ovaries will be large and bright yellow to bright orange in colour. The size can be up to 25% of the total body weight and the gonads will fill much of the body cavity. Individual eggs will be large, round and obvious, some eggs will be translucent. Pre-spawning condition can also be inferred by capture location. Females will usually only enter spawning condition once they are on the spawning grounds and around mature males. Thus a female caught away from the spawning grounds as the spawning season approaches is most likely still in pre-spawning condition, even if some sexual products can be extruded.

RIPE (RP): Fish in this category are sexually mature adults. *Ripe* is the term for the spawning condition. The *Ripe* category follows right after the *Pre-spawning* category, with respect to both time and stage of gonadal development, and occurs when the gametes (semen and eggs) have become loose in the gonads. This is a short term condition which extends from start to the end of spawning activity. Externally the fish will appear as they do during the *Pre-spawning* stage but extrusion of the gametes will occur in response to slight pressure on the abdomen.

Male: Externally the abdomen will be slightly distended. Semen can be extruded with light pressure to the abdomen. Large amounts of loose semen will be produced if pressure is applied. Internally, the testes will be large and white.

Female: Externally the abdomen will be greatly distended. Eggs immersed in ovarian fluid can be extruded with light pressure to the abdomen. Large amounts of loose eggs will be produced if pressure is applied. Internally, the ovaries will be large and yellow or orange. The eggs will be large and translucent and some will appear to be loose as the ovarian tissue is weak (i.e. the ovarian sac will be transparent and thin). Eggs will be loose inside the sac and they will be immersed in clear ovarian fluid.

SPENT (SP): Fish in this category are sexually mature adults. *Spent* is the term for the post-spawning condition. The *Spent* category follows right after the *Ripe* category, with respect to both time and stage of gonadal development, and occurs following spawning activity when the gametes (semen and eggs) have been largely extruded during spawning. This length of time a fish will spend in this category depends on how long it takes for the fish to begin the next cycle of seasonal gonadal development, at which time the fish will again be classified as *Green*.

Male: Externally, the abdomen will be slightly flaccid, especially ventrally. Some semen can still be extruded with pressure to the abdomen but it will most likely be watery (i.e. not as intense a white colour as in spawning males). Internally, the testes will be reduced in size and gray to creamy-white in colour. Hemorrhaging and distended blood vessels on the surface of the organ are common. Post-spawning males are known to stay on the spawning grounds for some time (up to 2 weeks) so capture location is not always a reliable indication of whether the fish has finished spawning.

Female: Externally, the abdomen will be noticeably flaccid, especially ventrally. The surface of the abdomen may be red or roughened with abrasions and the urogenital opening may be extended or swollen. Some eggs can still be extruded with pressure but will be few in number and they will be associated with watery ovarian fluid. Internally, the ovaries will be greatly reduced in size and dark orange to brown in colour. Hemorrhaging and distended blood vessels on the surface of the organ as well as within it are very common and normal. Some residual eggs (from a few up to 25% of the ovary volume) are common. It is not common for post-spawning females to stay on the spawning grounds, most spawn and leave the area immediately. However, capture location is not always reliable indicator.

REABSORBING (RB): Fish in this category are sexually mature fish which have developed to some extent for the coming spawning season but, instead of completing gonadal development or instead of spawning after completing gonadal development, these fish are reabsorbing materials from the gonads back into the body. This category represents arrested gonadal development or interrupted spawning activity. There are several reasons why a fish may terminate gonadal development or decide not to spawn after completing gonadal development. These include the condition of the fish with respect to nutrition and/or health, aspects of population dynamics or environmental cues such as improper water temperatures, poor water quality conditions or adverse water level conditions. Interrupted gonadal development can occur at any stage of development and prior to entering the reabsorbing category the fish may have been *Maturing*, undergoing *Seasonal Development* or in *Pre-spawning* condition.

Male: This condition is ***extremely rare in males*** and difficult to observe as reabsorption of the semen by the testes is usually a rapid process. Very rarely will a case be observed of a male actually retaining the entire contents of the testes for re-absorption. Should you suspect this condition the testes should be preserved and stage verified by a qualified biologist.

Female: This condition is primarily observed in females. Reabsorption of the eggs by the ovary is usually a lengthy process which can take up to a full year. Some females may retaining the entire contents of the ovaries for re-absorption. Identification of this stage is not always easy. Externally, the female will still have a distended abdomen if caught within a few months of the spawning season. The abdomen will feel unusually hard as compared to normally developing females. Later in the season, it will be impossible to distinguish a normally developing female from a reabsorbing one without an internal examination. Internally, reabsorbing ovaries go through a series of distinct stages. Early in the reabsorption process, the ovary is dark orange to brown in colour. The eggs are dark and flaccid. Heavy amounts of watery ovarian fluid collect at the posterior of the ovary. This fluid most often is ejected readily if the fish is handled. Later, the ovary becomes smaller and hard. The colour becomes darker and the eggs become atritic. Atritic eggs are easily identified as they are small, hard and white. Ovaries in the later stages of eggs reabsorption have few new oocytes. The remnants of the old eggs collect in the middle of the organ. New oocytes production is restricted to the periphery of the ovary. Should you suspect this condition the ovaries should be preserved and stage verified by a qualified biologist. Occasionally, females have been observed which aborted spawning activity after they had became *Ripe*. Functionally speaking, eggs at this stage are no longer connected to the ovaries and cannot be reabsorbed. Instead they remain in the body cavity. Internal examination of a fish in this condition will show the newly developed gonad as well as residual (brown, desiccated) eggs which could not be reabsorbed in the posterior portion of the body cavity.

RESTING (RS): Fish in this category are sexually mature adults which have spawned in one or more previous spawning seasons but **will not** spawn in the coming spawning season. These fish are different from *Reabsorbing* fish in that their gonads are either not developing or are developing too slowly to be ready for the upcoming spawning season. This is a common condition for fish which do not spawn every year (alternate year spawners).

Male: This condition is ***extremely rare in males***. It can **only** be used as an alternative to the Green category. A few cases of males in the resting condition have been observed. They are most common in northern latitudes where the growing season is short or in ultra-oligotrophic lakes. Testes will appear flaccid and dirty-white to yellow in colour. They will be larger in size than the testes of immature fish. A good indication is the size of the testicular artery in relation to the organ. In immature fish this artery is very thin whereas in resting males the testicular artery is much larger because of prior testicular development. Should you suspect this condition the testes should be preserved and stage verified by a qualified biologist.

Female: This condition is primarily observed in females but is still relatively infrequent, affecting usually only 0.5 to 1% of the population. This stage can **only** be used as an alternative to the *Green* category. It is most common in northern latitudes where the growing season is short or in ultra-oligotrophic lakes. The ovaries will appear to have some oocytes but they will be few in number and arrested in their development. The colour of resting ovaries varies greatly with fish species but most often they are a light orange. They will be larger in size than the ovaries of immature fish. A good indication is the size of the ovarian artery in relation to the organ. In immature fish this artery is very thin whereas in resting females the ovarian artery is much larger because of prior egg development. Should you suspect this condition the ovaries should be preserved and stage verified by a qualified biologist.

FIGURE 1:

PROTOCOL FOR FISH HEALTH SAMPLING AT METALS SITES

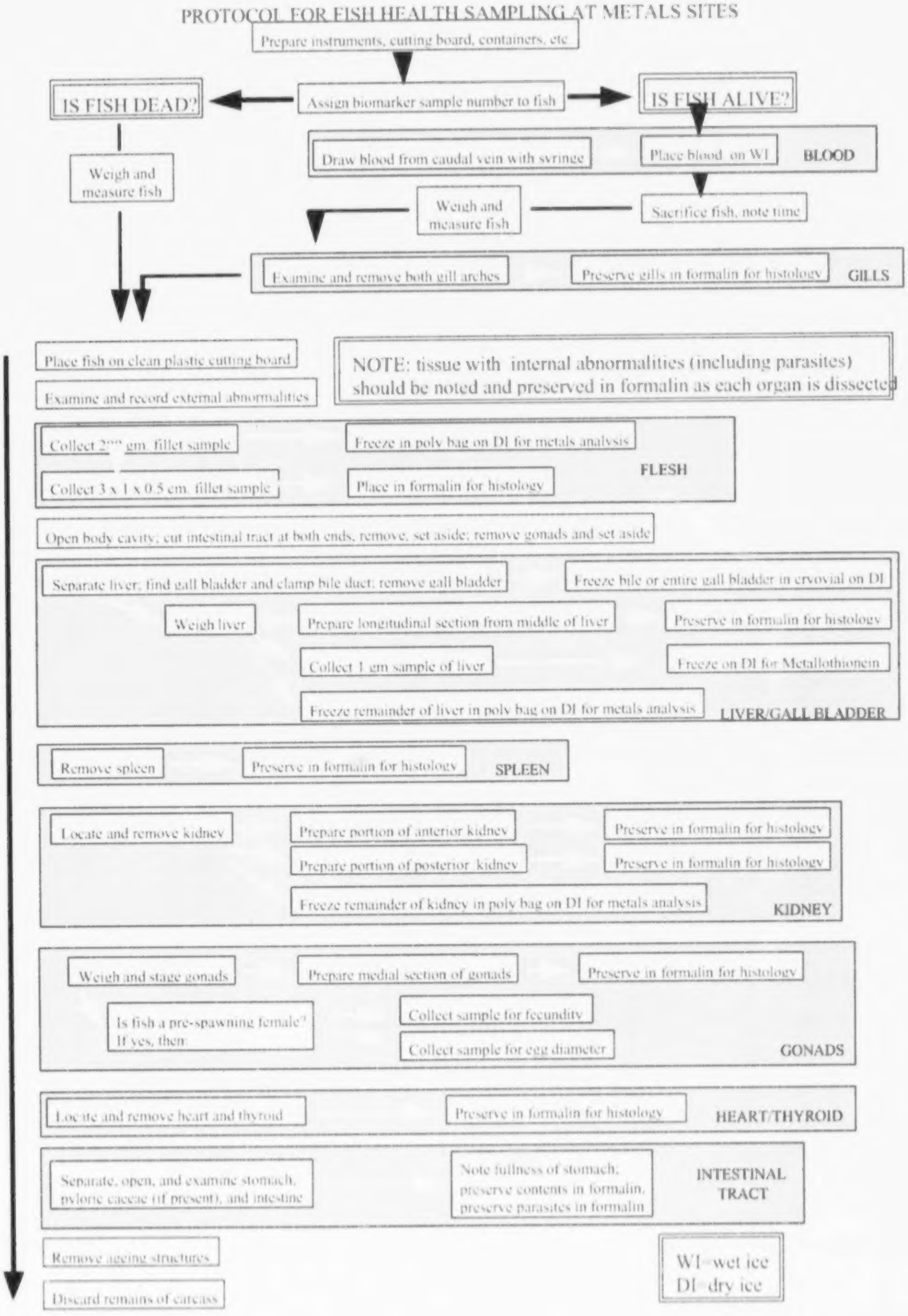
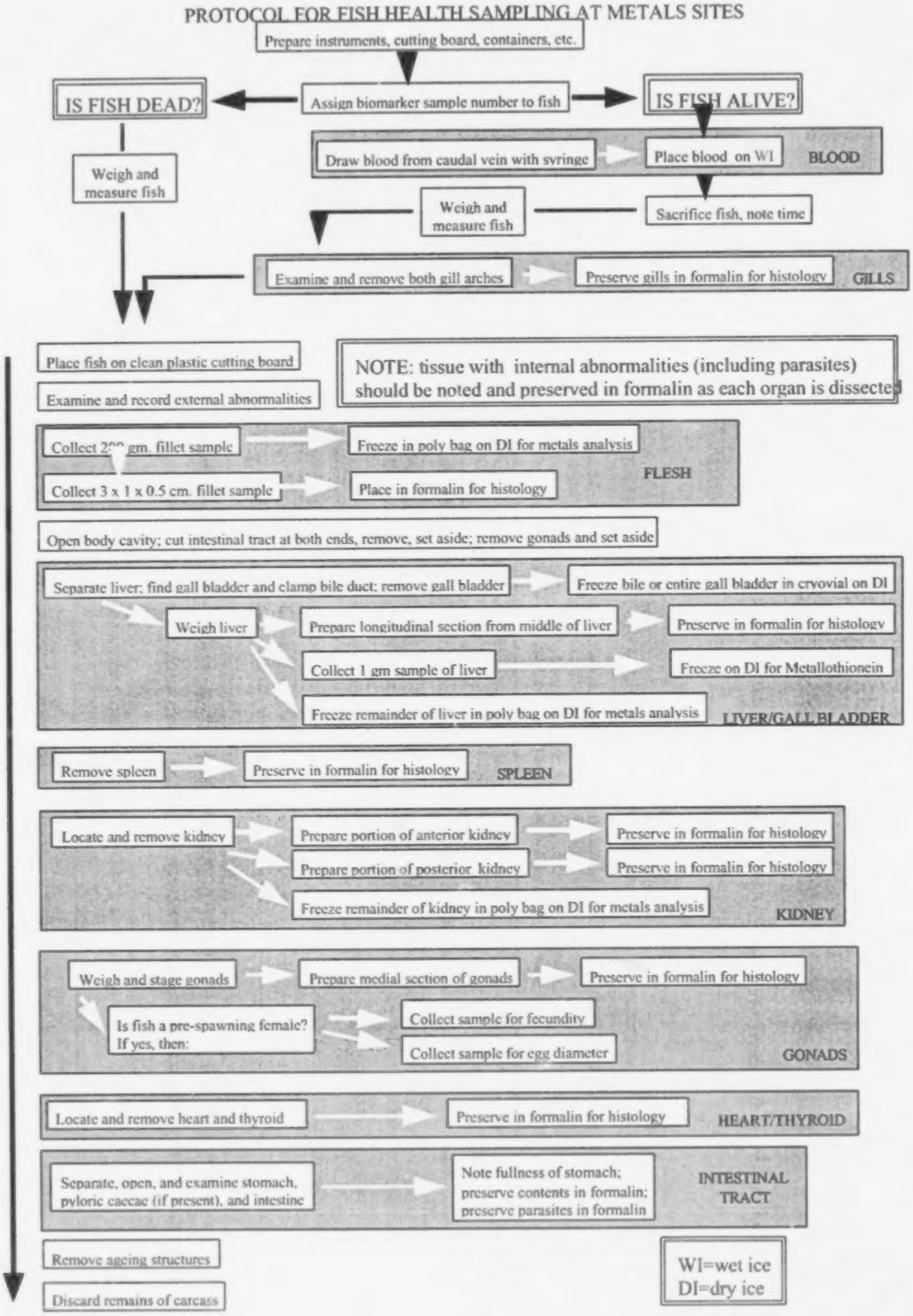

Prepare instruments, cutting board, containers, etc
Assign biomarker sample number to fish
IS FISH DEAD?
IS FISH ALIVE?
Draw blood from caudal vein with syringe
Place blood on WI
BLOOD
Weigh and measure fish
Weigh and measure fish
Sacrifice fish, note time
Examine and remove both gill arches
Preserve gills in formalin for histology
GILLS
Place fish on clean plastic cutting board
Examine and record external abnormalities
NOTE: tissue with internal abnormalities (including parasites) should be noted and preserved in formalin as each organ is dissected
Collect 200 gm. fillet sample
Freeze in poly bag on DI for metals analysis
Collect 3 x 1 x 0.5 cm. fillet sample
Place in formalin for histology
FLESH
Open body cavity; cut intestinal tract at both ends, remove, set aside; remove gonads and set aside
Separate liver; find gall bladder and clamp bile duct; remove gall bladder
Freeze bile or entire gall bladder in cryovial on DI
Weigh liver
Prepare longitudinal section from middle of liver
Preserve in formalin for histology
Collect 1 gm sample of liver
Freeze on DI for Metallothionein
Freeze remainder of liver in poly bag on DI for metals analysis
LIVER/GALL BLADDER
Remove spleen
Preserve in formalin for histology
SPLEEN
Locate and remove kidney
Prepare portion of anterior kidney
Preserve in formalin for histology
Prepare portion of posterior kidney
Preserve in formalin for histology
Freeze remainder of kidney in poly bag on DI for metals analysis
KIDNEY
Weigh and stage gonads
Prepare medial section of gonads
Preserve in formalin for histology
Is fish a pre-spawning female? If yes, then
Collect sample for fecundity
Collect sample for egg diameter
GONADS
Locate and remove heart and thyroid
Preserve in formalin for histology
HEART/THYROID
Separate, open, and examine stomach, pyloric caecae (if present), and intestine
Note fullness of stomach; preserve contents in formalin, preserve parasites in formalin
INTESTINAL TRACT
Remove ageing structures
Discard remains of carcass
WI=wet ice
DI=dry ice

FIGURE 1:

PROTOCOL FOR FISH HEALTH SAMPLING AT METALS SITES


Prepare instruments, cutting board, containers, etc.
IS FISH DEAD?
Assign biomarker sample number to fish
IS FISH ALIVE?
Weigh and measure fish
Draw blood from caudal vein with syringe
Place blood on WI
BLOOD
Weigh and measure fish
Sacrifice fish, note time
Examine and remove both gill arches
Preserve gills in formalin for histology
GILLS
Place fish on clean plastic cutting board
Examine and record external abnormalities
NOTE: tissue with internal abnormalities (including parasites) should be noted and preserved in formalin as each organ is dissecte
Collect 2[illegible] gm. fillet sample
Freeze in poly bag on DI for metals analysis
Collect 3 x 1 x 0.5 cm. fillet sample
Place in formalin for histology
FLESH
Open body cavity; cut intestinal tract at both ends, remove, set aside; remove gonads and set aside
Separate liver; find gall bladder and clamp bile duct; remove gall bladder
Freeze bile or entire gall bladder in cryovial on DI
Weigh liver
Prepare longitudinal section from middle of liver
Preserve in formalin for histology
Collect 1 gm sample of liver
Freeze on DI for Metallothionein
Freeze remainder of liver in poly bag on DI for metals analysis
LIVER/GALL BLADDER
Remove spleen
Preserve in formalin for histology
SPLEEN
Locate and remove kidney
Prepare portion of anterior kidney
Preserve in formalin for histology
Prepare portion of posterior kidney
Preserve in formalin for histology
Freeze remainder of kidney in poly bag on DI for metals analysis
KIDNEY
Weigh and stage gonads
Prepare medial section of gonads
Preserve in formalin for histology
Is fish a pre-spawning female? If yes, then:
Collect sample for fecundity
Collect sample for egg diameter
GONADS
Locate and remove heart and thyroid
Preserve in formalin for histology
HEART/THYROID
Separate, open, and examine stomach, pyloric caecae (if present), and intestine
Note fullness of stomach; preserve contents in formalin; preserve parasites in formalin
INTESTINAL TRACT
Remove ageing structures
Discard remains of carcass
WI=wet ice
DI=dry ice

FISH HEALTH ASSESSMENT

Waterbody:________________________ Site:________________________ Date: ____________________

Fish Species:_________ Biomarker Fish # ____________________ Fisheries Inventory # ______________

Fork length (mm):____________Total Length (mm) ______________Total Weight (g):_____________________

Carcass Weight (g): __________Capture Method:___________ Aging Structure Taken: FR Sc Ot Op Cl

Internal and External Examination

Eyes:
N B1 B2 E1 E2 H1 H2 M1 M2 OT(other):__________________

Gills:
N F C M P OT (other):________________________

Pseudobranchs:
N S L I OT (other):________________________

Thymus:
0 1 2 3 comments:________________________

Skin:
0 1 2 3 comments:________________________

Bodyform Deformities:
Description:____

Fins
0 1 2 3 comments:________________________

Opercles:
0 1 2 comments:________________________

Hindgut:
0 1 2 3 comments:________________________

Sex:
M F U Maturation stage: IM MA SD PR RP SP RS RB UN

Mesenteric Fat
0 1 2 3 4 comments:________________________

Liver:
A C D E F OT (other):________________________

Spleen
B G D E OT (other):________________________

Gall Bladder:
0 1 2 comments:________________________

Kidney:
N S M G U OT (other):________________________

Parasites:
0 1 2 3 comments:________________________

General Comments:____
____
____
____
____

BIOMARKER DATA Project No.____________ CUTTER:____________ (Full name)

Waterbody:__________________ Site:______________________ Species:______________________

Biomarker Fish #:______________________ Fisheries Inventory #:____________________

Fork length (mm): ____________ Total length (mm):______________ Total Weight (g): __________

Carcass Weight (g) __________ Sex:____________________ Maturity:__________________

Capture Time: Date __________________ Hr. ____________ Capture Method: __________

Sacrifice Time: Date ________________ Hr. ______________ Sacrifice Method: _________

COLLECTION DETAILS:

STOMACH:
Observed: ________
Collected: ________
% Fullness: ________
Description/% of Contents:__________________
Other Observations:______________________

HISTOLOGY EXAMINATION:

	Abnormality	Preserved (g)
Liver	________	________
Spleen	________	________
Heart	________	________
Gill	________	________
Kidney	________	________
Other	________	________

BLOOD: Time Taken ________
Total Volume: _____ mL
Time of Centrifugation: ________
Plasma Volume: _____ mL
Plasma Colour: ________
Hematocrit: ______ %
______ %
Leucocrit: ______ %
______ %
Plasma Protein: _____g/dL

LIVER: MFO / MT: _______ g
Contaminants: _______ g
Histology: _______ g
Archive: _______ g
Total Liver Weight: _______ g
Time MFO Sample Taken: ________

KIDNEY: MT: _______ g
Contaminants: _______ g
Histology: _______ g
Total Kidney Weight: _______ g

FILLETS: Organics: _______ g
Metals: _______ g
Other: _______ g

BILE: Gall Bladder Fullness (%): ________
Colour: ________
Volume Collected: _____ mL

GONADS: Contaminants: _______ g
Histology: _______ g
Region Collected From: ________

Fecundity Subsample Weight: _______ g
Region Collected From: ________
No. of Eggs in Subsample: ________

Ave. Egg Diameter: _____ mm
No. of Eggs Measured: ________

Total Gonad Weight _______ g

Recorder (Full Name)____________________

VARIABLE	VARIABLE CONDITION	ORIGINAL FIELD DESIGNATION
Eyes	No aberrations; good "clear" eye	N
	Blind; an opaque eye (one or both)	B
	Swollen, protruding eye (one or both)	E
	Hemorrhaging or bleeding in the eye (one or both)	H
	Missing one or both eyes	M
	Other; any manifestation not fitting the above	OT
Gills	Normal; no apparent aberrations	N
	Frayed; erosion of tips of gill lamellae resulting in "ragged" gills	F
	Clubbed; swelling of the tips of the gill lamellae	C
	Marginate; gills with light, discolored margin along tips of the lamellae	M
	Pale; very light in color	P
	Other; any observations not fitting above	OT
Pseudobranchs	Normal; flat, containing no aberrations	N
	Swollen; convex in aspect	S
	Lithic; mineral deposits, white, somewhat amorphous spots	L
	Inflamed; redness, hemorrhage, or other	I
	Other; any condition not covered above	OT
Thymus	No hemorrhage	0
	Mild hemorrhage	1
	Moderate hemorrhage	2
	Severe hemorrhage	3
Skin	Normal; no aberrations	0
	Mild skin aberrations	1
	Moderate skin aberrations	2
	Severe skin aberrations	3
Fins	No active erosion	0
	Light active erosion	1
	Moderate active erosion with some hemorrhaging	2
	Severe active erosion with hemorrhaging	3
Opercle	No shortening	0
	Mild shortening	1
	Severe shortening	2
Hindgut	Normal; no inflammation or reddening	0
	Slight inflammation or reddening	1
	Moderate inflammation or reddening	2
	Severe inflammation or reddening	3
Mesenteric Fat	None	0
	< 50 %	1
	50 %	2
	> 50 %	3
	100 %	4
Liver	Normal; solid red or light red color	A
	"Fatty" liver; "coffee with cream" color	C
	Nodules in the liver; cysts or nodules	D
	Focal discoloration; distinct localized color changes	E
	General discoloration; color change in whole liver	F
	Other; deviation in liver not fitting other categories	OT
Spleen	Normal; black, very dark red, or red	B
	Granular; rough appearance of spleen	G
	Nodular; containing fistulas or nodules of varying sizes	D
	Enlarged; noticeable enlarged	E
	Other; gross aberrations not fitting above categories	OT
Gall Bladder	Normal	0
	Enlarged	1
	Parasites	2
Kidney	Normal; firm dark red color, lying relatively flat along the length of the vertebral column	N
	Swollen; enlarged or swollen wholly or in part	S
	Mottled; gray discoloration	M
	Granular; granular appearance and texture	G
	Urolithiasis or nephrocalcinosis; white or cream-colored mineral material in kidney tubules	U
	Other; any aberrations not fitting previous categories	OT
Parasites	No observed parasites	0
	Few observed parasites	1
	Moderate parasite infestation	2
	Numerous parasites	3

Maturity Codes: IM = Immature MA = Maturing SD = Seasonal Development PR = Pre spawning RP = Ripe SP = Spent RS = Resting RB = Reabsorping UN = Unknown

Golder Associates

GOLDER ASSOCIATES LTD.
CHAIN-OF-CUSTODY RECORD
AND ANALYTICAL REQUEST FORM

Page ____ of ____

Field Sampler: (Signature) ______________________________

Phone No.: ______________________

Shipment Date: ______________________

Carrier: ______________________

Waybill No.: ______________________

Ship To:

Send Results To:

Project Name: ______________________________

Project No: ______________

P.O. No.: ______________

Relinquished by: (Signature)	Received by: (Signature)	Date:	Time:
Relinquished by: (Signature)	Received at lab by: (Signature)	Date:	Time:
Relinquished by: (Signature)	Received at lab by: (Signature)	Date:	Time:
Relinquished from lab by: (Signature)	Received by: (Signature)	Date:	Time:

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt

Special Instructions/Comments:

Rush (surcharge): ______________ Standard Turnaround Time: ______________

WHITE COPY	RETURN TO GOLDER ASSOCIATES LTD.
YELLOW COPY	LABORATORY COPY
PINK COPY	RETAINED BY FIELD CREW LEADER

GOLDER ASSOCIATES LTD.
CHAIN-OF-CUSTODY RECORD
AND ANALYTICAL REQUEST FORM

Page ____ of ____

Field Sampler: (Signature) ______________________

Phone No.: ______________________

Shipment Date: ______________________

Carrier: ______________________

Waybill No.: ______________________

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt

Special Instructions/Comments:

Rush (surcharge): ______________________

Standard Turnaround Time: ______________________

WHITE COPY	RETURN TO GOLDER ASSOCIATES LTD.
YELLOW COPY	LABORATORY COPY
PINK COPY	RETAINED BY FIELD CREW LEADER

APPENDIX V

FISH POPULATIONS

Appendix V.1 Photographs of Fish Sampling Locations

Photographs – Study Lakes

↑ Photograph V.1 Consecon Lake (reference lake for white sucker), Moira River System, Fall 1999.

↑ Photograph V.2 Round Lake (reference lake for white sucker), Moira River System, Fall 1999.

Photographs – Study Lakes

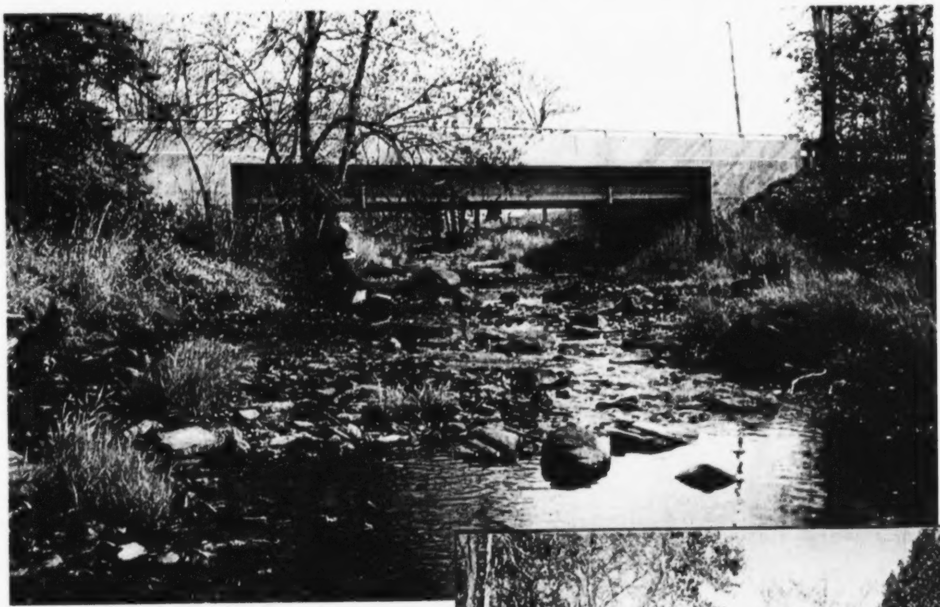
↑ Photograph V.3 Moira Lake (exposed lake for white sucker), Moira River System, Fall 1999.

↑ Photograph V.4 Stoco Lake (exposed site for white sucker), Moira River System, Spring 1999.

Photographs – Study Lakes

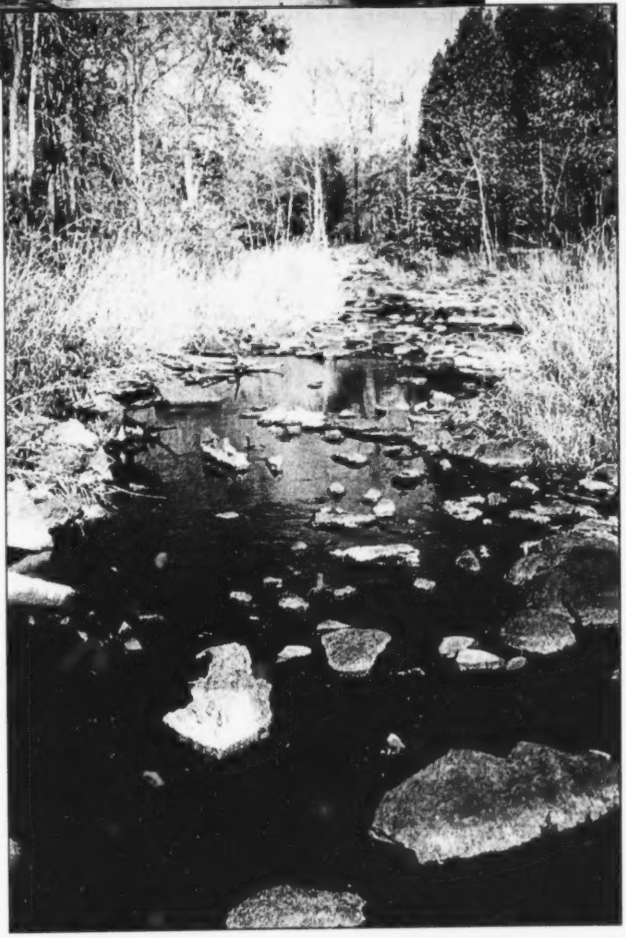
↑ Photograph V.5 Bend Bay (exposed river site for white sucker), Moira River System, Fall 1999.

Photographs – River Study Sites

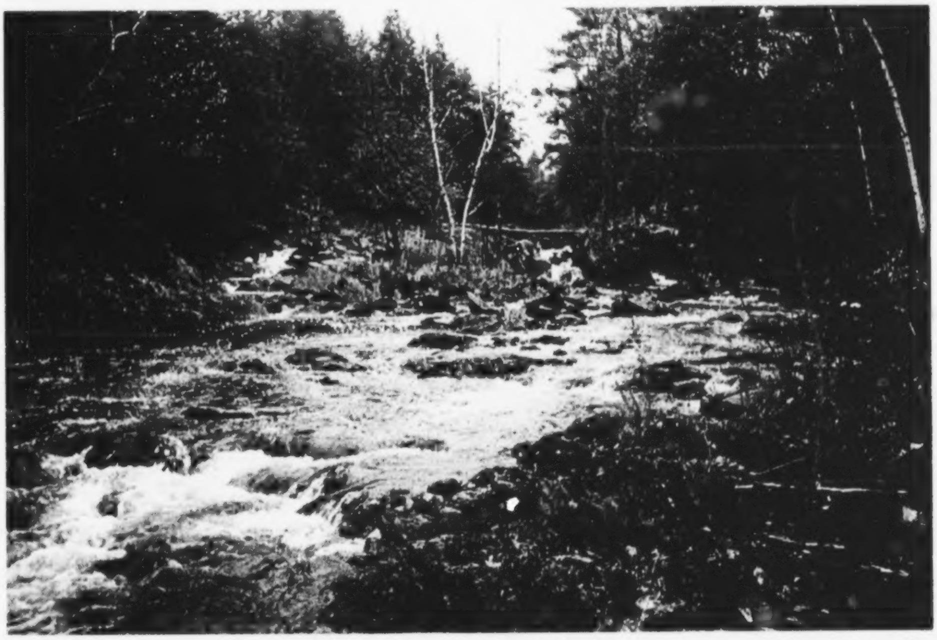


↑ Photograph V.6
Site F-1 (reference site for longnose sucker), Moira River System, Fall 1999 (view faces upstream).

→ Photograph V.7
Site F-2 (reference site for longnose dace), Moira River System, Fall 1999 (view faces downstream).



Photographs – River Study Sites



↑ Photograph V.8 Site F-3 (exposure site for longnose dace), Moira River System, Fall 1999 (view faces upstream).

Appendix V.2 **Golder Technical Procedure 8.1-3
Fish Inventory Methods**

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Appendix I Maturity Codes and Definitions

1 PURPOSE

This technical procedure presents the techniques and methodologies used for standard fisheries sampling during fish inventory studies for the purposes of determining species presence, distribution, relative abundance, basic population characteristics and for conducting population estimates. Decisions regarding the type of sampling gear to use, the specific techniques to be employed and the timing of sampling will be determined prior to the commencement of the field study by the project team or project manager. However, due to the nature of fisheries work, some decisions regarding sampling specifics will depend upon conditions in the field. The methods for general fisheries inventory work are covered in this technical procedure. Other technical procedures are required in addition to this one in order to conduct fish sampling for specific tasks such as biomarking/fish health studies. This technical procedure does not detail the Quality Assurance/Quality Control requirements for components of field programs, such as note taking/data recording, as they are included in other documents.

2 APPLICABILITY

This technical procedure is applicable to all personnel involved in fisheries surveys for lakes and streams, including all sizes and orders of streams. It covers sampling equipment and techniques currently owned/used by Golder. Additional techniques are available which may be the most suitable method for specific circumstances or project requirements. If this is the case, the project manager must authorize the use of any new technique or the purchase of additional equipment.

3 DEFINITIONS AND METHODS

3.1 Abundance, Relative

The proportional representation of a species in a sample or a community. In fisheries inventories, relative abundance is typically used to describe the relative number of fish captured for each different species at a sampling site. Relative abundance can also be determined for the same species at different sites or in different seasons. It can also be determined for different life stages of the same species.

In some limited cases, the number of fish captured can be used to describe relative abundance. This is suitable for a single effort in a single sampling area where relative abundance is simply the relative number of fish captured. For example, if 20 fish of one species and 10 fish of another species were captured in 100 seconds of electrofishing at a site, species one is determined to have a relative abundance twice that of species two.

For any sampling situation which is more complicated, Catch-Per-Unit-Effort (CPUE) values must be calculated to determine relative abundance. CPUE values take into account the sampling effort required to catch the fish as well as the number of fish captured. For example, if 20 fish of one species were captured in 100 seconds of electrofishing at one site, and 20 fish of the same species were captured in 200 seconds of electrofishing at a second site, CPUE data shows that this species has a relative abundance at the first site which is twice that of the second site. In this example, twice the effort was required to capture the same number of fish at site two. This example also shows why it would be unsuitable to derive conclusions about relative abundance based solely on the numbers of fish captured.

In order to be able to determine relative abundance, you must record all sampling efforts in a manner suitable for calculating CPUE data.

3.2 Ageing Structures

Ageing structures are bony parts of the fish which are taken for ageing analyses. In fish from temperate zones, these structures contain annual bands (annuli) which delineate seasonal variation in growth which can be counted to determine the fishes' age. Primary examples of these structures are scales, fin rays, saggital otoliths, cleithra and opercula. The appropriate ageing structures to collect vary according to fish species and life stage and include lethal and non-lethal sampling measures. Consult the table of "**Recommended Fish Ageing Structures**" (available in the aquatics reference file) for the appropriate structure and collection method for each species. With respect to fish ageing, all procedures used by Golder (i.e., the ageing structures which are collected and the methods used to determine age) conform to the manual of Fish Ageing Methods for Alberta (Mackay et al. 1990).

Following removal from the fish, ageing structures should then be placed in a "scale envelope", which consists of a small envelope which has been stamped with fields for recording the following information:

- date
- fish number
- species
- fork length
- weight
- life history stage
- sex
- state-of-maturity
- sampling gear
- sampling location
- ageing structure collected
- project number

Blank envelopes are ordered in batches of 1000 and must be stamped prior to use. If your project includes the collection of ageing structures, it may be necessary to order the required envelopes and stamp them before heading out into the field.

The scale envelopes should be allowed to dry overnight before being stored. Upon returning from the field, the envelopes should be stored frozen in a one of Golder's freezers.

3.3 Anaesthetic

An anaesthetic is used in situations requiring live fish to be removed from the water and handled for extended periods, such as during surgery to implant radio transmitters, or to quiet fish for measurements. The anaesthetic commonly used by Golder is MS-222, known as tricaine methanesulfonate. The concentration of anaesthetic to be used depends on the required level of sedation. For surgery, which requires the fish to remain sedated for a period of 5-10 minutes, a concentration of 100 mg/L is used (i.e. 4 g of MS-222 in 40 L of water). The fish is placed in the anaesthetic bath for 2-4 minutes until the desired level of sedation is reached. Care must be taken as overdoses lead to direct mortality. When monitoring the fish in the anaesthetic solution, watch for loss of coordination (when the fish no longer keeps itself upright) and respiration rate. Towards the end of the anaesthetization period, the fish will begin to "Cough".

Use of anaesthetic for quieting fish for measurements is not typically recommended unless the fish is difficult to handle or may injure itself. Fish anaesthetized with MS-222 are not recommended for consumption by anglers for a period of 2-4 weeks following exposure to the anaesthetic. Therefore, use only on fish which will not be captured and consumed or with permission of Alberta Fisheries Management Division.

3.4 Biomass

Biomass is the total mass (weight) of fish, or of fish of a given species, within a study area. It is a component of population estimates, as an estimate of the total number of fish in the study area is required to calculate biomass. Using either total removal data or a mark/recapture population estimate for the study site, the total biomass is calculated by multiplying the total population of fish by the average weight of the fish captured. Results can be expressed as units of weight over study area dimensions (e.g. kg/m of stream, kg/m^2 of lake).

3.5 Capture/Sampling Techniques

The following sampling techniques are used to capture fish. Some techniques are very specific to one life stage while others are more general. All sampling techniques have some degree of sampling bias associated with them with respect to fish size selectivity and sampling efficiencies based on environmental parameters such as water depth, conductivity, stream size etc. It is important to understand these biases when designing or implementing a study plan and when interpreting the data and drawing conclusions from the results.

3.5.1 Airlifting

Airlift sampling is used to collect fish eggs from the substrate for species which are broadcast spawners (i.e. do not bury their eggs). It can be used simply to determine if incubating eggs are present or to determine the relative density of eggs at each spawning site. The airlift sampler consists of a gas powered generator and compressor unit, a length of hose, an airlift head and couplers to connect the hose to the compressor and airlift head. The airlift head is attached to a long pole and consists of a 4" or 6" diameter hollow tube with a 90° bend at the upper end. The lower end of the airlift head has an internal tube which runs around the internal circumference and which is perforated. With the lower end of the airlift head held against the substrate, air is pumped from the compressor through a hose and into the perforated tube. Air rising inside the airlift head creates a vacuum effect which lifts loose particles up from the substrate. A removable collection bag placed over the upper end of the airlift head collects the particles. The sample is dumped into a sampling tray and examined for the presence of eggs.

This technique is employed when sampling water too deep to kick sample or when a quantitative sample is required. Since the area (cm^2) of the airlift head is known, simply count the number of times the head is touched to the substrate for each sample in order to determine the number of eggs/cm^2 in the sample. Quantitative sampling can be used to determine the relative use of the spawning areas sampled, as determined by egg density. Remember to record the size of the airlift head used.

3.5.2 Angling

Angling refers to the use of angling gear, such as rod and reel, to sample for fish. Angling is an active technique using lures, bait or flies. Leaving a static, baited line in one place is referred to as a Set Line and is not an angling technique. On the other hand, jigging with a baited line would be an angling technique.

Sampling effort should be recorded as both the number of hours angled and the number of angling tools used. It would be recorded as angler-hours, or as rod-hours or some equivalent if more than one piece of angling gear is used per angler. The types of hooks, size of hooks, and number of hooks should also be recorded. In addition, notes on the types of habitats fished and the length of shore line covered if trolling is conducted should be recorded.

3.5.3 Drift Net

Drift net is a passive sampling technique for use in flowing water for the capture of life stages which are moving or drifting downstream. A drift net consists of a long, tapering net with an open mouth at the upstream end and a detachable sample bottle at the downstream end. Drift nets are anchored in place in the stream and filter the water passing through them, collecting materials from the water column. They can be placed to sample the bottom, middle or top of the water column or can be stacked to sample the entire water column. At regular intervals, the nets are removed and cleaned by dumping the collection jars into a sampling tray and examining the sample for the presence of fish. Typically the drift nets are checked and cleaned twice per day, once first thing in the morning and once again in the evening. Record the catch separately for each period in order to be able to determine diurnal patterns.

Sampling effort is usually recorded as the number of hours between net cleanings to determine catch/hour. If more detail is required, it is also possible to estimate the volume of water sampled by the net during the period between net cleanings to determine the catch/m^3. To do this, measure the velocity of the water at the sampling site before setting the drift net and again after lifting the net for cleaning to determine the average water velocity through the net. Multiply the average velocity (m/s) by the area of the net mouth (m^2) to get the volume sampled per unit time (m^3/s) (remember to record the size of the drift net mouth). Multiply this value by the time the net was in place to calculate the total volume sampled. For this calculation, the drift net mouth must be completed submerged.

3.5.4 Electrofishing

Electrofishing refers to the use of electricity to stun and capture fish. An electrical current is passed between electrodes placed in the water and the resulting electrical field attracts passing fish (galvanotaxis) toward the positive electrode (anode). As fish pass close to the anode they encounter an increasingly stronger current gradient which acts as a narcotic and stuns the fish (galvanonarcosis), allowing them to be easily dip-netted from the water. Once captured, the fish may be identified, weighed, measured, tagged and then returned to the water. Fish taken by electrofishing revive quickly when returned to the water. Effort is automatically recorded by the electrofishing unit as the number of seconds of active electrofishing (i.e. the time current is applied to the water). **Record the effort (seconds) immediately after completion of sampling and reset the timer to zero.** Electrofishing techniques require experienced operators in order to reduce injury to the fish and to eliminate potential injury to the personnel involved. Safety training or working with experienced personnel is required for operating electrofishing equipment.

Backpack Electrofishing

Backpack electrofishing is a sampling technique for small, wadable streams. A backpack electrofisher consists of a portable electrofishing unit and a power source (12v battery or mini generator) attached to a pack frame. It is equipped with a hand held, button-operated anode pole and a cathode plate which is left trailing in the water. The operator wears the pack unit and uses the button switch to activate the anode in order to stun fish while wading instream. One or more assistants wading next to the operator use dip nets to capture the stunned fish. The assistant also adjusts the electrofisher settings for the operator and monitors the electrical output. Sampling is normally conducted while moving upstream so that fish are not disturbed, prior to being sampled, by disturbances to the stream bed and material moving downstream with the flow.

Boat Electrofishing

Boat electrofishing is an extremely effective sampling technique for moderately shallow water and is used for intermediate streams, large rivers and shallow littoral areas in lakes. Two types of boat electrofisher are available, both of which consist of an electrofishing control box which is powered by a 5,000 watt generator. The ***portable boat electrofisher*** has a free control box and generator which can be loaded into an inflatable boat (Zodiac) and is ideal for small or intermediate sized rivers which cannot be waded and which cannot be effectively sampled by the low current outputs provided by a backpack electrofisher. Two anode configurations are possible, depending on stream size, and include either a hand-held, button operated anode pole or a foot-switch operated portable boom system. In both cases, a floating cathode plate is employed. The boat can be drifted downstream or an outboard jet can be used to provide increased mobility. In comparison, an ***electrofishing boat*** consist of an 18' aluminum river boat with an integral electrofisher control box and generator. It is also equipped with a work platform and flow-through live well for holding fish. It has a foot-switch operated anode boom system and uses the boat hull as the cathode. Boat electrofishers are designed for any intermediate or large river which is deep enough to allow a boat of this size to float and which has a site with a suitable boat launch. This unit has the largest anode/cathode surface area and is capable of generating the largest electrical field and the highest current outputs. Boat electrofishing sampling for both types of units is usually conducted while floating downstream, as this makes fish easier to dipnet and puts less stress on the dipnets and anodes.

3.5.5 Emergent Trap

An emergent trap is a passive sampling technique specifically designed to capture fry as they emerge from the substrate following hatching. A typical emergent trap consists of a square metal frame (0.3m x 0.3m) covered with a small mesh net and collection bottle. The mouth of the trap is placed on top of the substrate at a known or suspected spawning area where incubating eggs are known or thought to be present. It is left in place through the incubation period. Once the fry have hatched and absorbed their yolk sacs they emerge from the substrate. The fry from the eggs which were located under the trap mouth will be captured by the trap.

Emergent traps can be used to verify a suspected spawning area or to check for hatching success at a know spawning site.

3.5.6 Fry Traps

A fry trap is a passive sampling technique used to capture fry which are drifting downstream in flowing water. It is suitable for capturing fry which are larger than post-emergent size but which are not yet strong swimmers. The fry trap is anchored to the stream bed using 2 rebar posts and consists of a large metal frame open at the upstream end and otherwise covered with small mesh metal screening. "Wings" lead from the trap mouth into a low velocity area at the downstream end of the trap where the fry accumulate. The trap is designed so that it will pivot at the anchor point on the stream bed. To check the trap, simply tilt it forward and hold a collection bucket in front of the "top" of the low velocity holding cell. Water and fry from the holding cell will pour into the bucket as the trap is tilted. Typically the traps are checked and cleaned twice per day, once first thing in the morning and once again in the evening. Record the catch separately for each period in order to be able to determine diurnal patterns.

Sampling effort is usually recorded as the number of hours between trap cleanings to determine catch/hour. If more detail is required, it is also possible to estimate the volume of water sampled by the trap during the period between trap cleanings to determine the catch/m^3. To do this, measure the depth and velocity of the water at the sampling site before setting the trap and again after checking the trap to determine the average water depth and velocity through the trap during the sampling period. Multiply the average depth (m) by the average velocity (m/s), then by the width of the trap mouth (m) to get the volume sampled per unit time (m^3/s) (remember to record the width of the trap mouth). Multiply this value by the time the trap was in place to calculate the total volume sampled.

3.5.7 Gill Netting

A method of capturing fish that involves the setting of nets of various mesh sizes anchored in place in a river or lake. A gill net consists of netting suspended between a weighted "lead" line and buoyant "float" line which, when set, forms a vertical wall of netting. The lead line is attached at both ends to heavy weights to hold it in place and keep the net taught. The float line is attached at either end to floats. In Alberta, the floats must each consist of a pole which stands upright at the water surface and extends above the water surface for a minimum of 1.0 m. The top of the poles must have a blaze red or orange flag measuring at least 20 cm x 20 cm and marked with the Fish Collection Licence Number in 20 mm high letters. Typically, we use sandbags filled with rocks or sand from the gill net site for lead line weights. This way, all we have to carry with us to the site is a few empty sandbags. New gill nets need to have a length of sideline attached to either end which extends from the float line to the lead line to take the tension when the net is lifted to ensure that the mesh does not rip.

Gill nets are designed to function by catching on the gill covers of fish as they attempt to swim through. Fish of a size for which the gill net mesh size is designed swim into the net but can only pass partway through the mesh. When the fish struggles the twine slips behind the gill covers (opercula) and the fish becomes "gilled". Therefore, the mesh size of the gill net is important when selecting a net or nets for your sampling activity as gill netting can be a very size selective technique.

Gill net mesh size can be measured as either the stretch measure or square measure of the openings in the mesh. At Golder, we always use the stretch measure to identify our gill nets and when reporting results. The stretch measure is the distance between two opposite corners of the square mesh opening, when the square is stretched flat. Gill net mesh sizes typically range from 1.9 to 14.0 cm (3/4"-5.5"). As most gill nets are sold using imperial units of measure, the following table will help you convert mesh sizes to metric units.

Stretch Mesh Sizes:											
Imperial (inches)	3/4	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
Metric (cm)	1.9	2.5	3.8	5.1	6.3	7.6	8.9	10.2	11.4	12.7	14.0

Gill net meshes are constructed either of monofilament or nylon. Monofilament is sturdier and longer lasting but gill nets made from this material do not compress and take up a much larger volume than a nylon net of the same dimensions. For longer nets, the volume of a monofilament net becomes significant.

Gill nets can be simple or multi-mesh. Simple nets consist of one mesh size only, although different nets may have different lengths and depths. Multi-mesh nets are also called "gang" nets and consist of more than one mesh size. Each mesh size occurs in a discreet section of the net which is called a panel. Gang nets typically have from two to five different mesh sizes or panels. Usually, each panel has the same length, although this is not always the case. An important component of recording sampling effort is to record the dimensions of all gill nets that are set. Record the depth of each net as well as the total length. Also record the number of panels, the mesh size of each panel and the length of each panel. Effort should also be recorded as the number of hours the net is set and CPUE is expressed as either duration (hrs), panel-hours, or meter-hours, depending on the type and variety of nets set.

Since the size of the mesh will have a major role in determining the size of fish (i.e. species or life stages) that will be captured, it is extremely important to record the mesh sizes of any gill net used. It is also important to record the catch for each individual panel or mesh size. The field form used to record the catch has a space for recording the mesh size for each fish captured. When removing fish from the gill net, the fish must be separated by mesh size.

Selecting a gill net or nets to be used for a project will vary depending on your sampling goals. Long gang nets with several different mesh sizes, from small to large mesh, are best for general inventory sampling and have the smallest level of sampling bias. For single mesh nets or nets with few panels, it is generally true that the larger the mesh size used the larger the fish that will be captured. The small 1.9 cm mesh nets will capture fish as small as the larger minnow species and juvenile life stages of larger fish. Mesh sizes in the range of 5.1-7.6 cm are typically used for salmonid species while larger mesh sizes will be employed to capture adult northern pike and burbot. Most gill nets will capture a larger size range of fish than mesh size would dictate as some species will be captured without necessarily being "gilled". For example, suckers may be entangled by their large lips and northern pike often bite and roll in the mesh, becoming entangled in mesh sizes too small to capture them by gilling. Bullheads on the other hand are often captured in mesh sizes too large to gill them when their pectoral and dorsal spines become entangled in the mesh.

Nets selected for sampling in rivers are generally different from those used in lakes. River gill nets typically have large floats attached to the float line for added buoyancy. Shorter nets are used as they must be set in low velocity pockets such as backwaters or pools and heavy weights are used to anchor the net so that it will remain in position in flowing water. Caution should be taken when setting nets in a river at high stage if floating debris is moving downstream which could damage or move the net. In lakes, much longer nets can be used if required and, since lakes typically have greater depths than rivers, nets can be set at a variety of depths. Lake nets can be set so that they float near the surface, are set along the lake bed or are positioned in mid column. For floating sets, nets with large floats attached to the float line can be used and long leads are tied to the weights to allow the net to remain at the surface. For sinking sets, nets without additional floats or with small floats are used. For bottom sets, the weights are tied tight to the lead line and long leads are tied to the floats so that the net will sit on the bottom and the floats will remain at the surface. For mid column sets, leads are attached to both the weights and floats so the net will be positioned between the bottom and the surface.

Gill netting is a sampling technique that can be used in the winter as nets can be set under the ice. In lakes where there is no current a jigger is used to run a length of sideline under the ice. A large hole is opened in the ice and the jigger is placed under the ice. The sideline is tied to the jigger and the lever arm is manipulated to send the jigger moving away from the hole. Once the jigger has moved far enough it must be relocated, either by sight if the ice is clear or by sound as the jigger is equipped with a "clicker" device. A hole is drilled at the location of the jigger and a hook is used to pull the sideline up the hole. In rivers or in the case of thick lake ice a Murphy stick is used to set the net. A Murphy stick consists of two sections of aluminum pipe hinged together which extends as an under-ice probe. The far end of the probe has an eye-hook at the end and a float a short distance back. A length of sideline a little longer than the gill net is tied to the eye-hook and the far end of the probe is pushed down through one hole in the ice and manoeuvred towards a second hole where the attached sideline is hooked and pulled up through the hole. The process is repeated several times to extend the rope as far as desired. Once the sideline has been placed under the ice it is then attached to one end of the gill net and used to pull the net under the ice.

As a sampling technique, gill nets can have a high mortality rate if the fish are left in the net for a prolonged period or if water temperatures are high. If fish mortality is a concern, the nets should be cleaned of fish on a regular basis (e.g. every two hours). If mortality is desirable (i.e. fish are to be sacrificed) or not a concern, nets should be set overnight in order to sample day and night periods of fish movements and to allow capture of fish which may avoid the net if it is visible during daylight hours in low turbidity water.

3.5.8 Hoop Net (Fyke Net)

A hoop net is cylindrical net distended by a series of hoops or frames with one or more internal funnel-shaped throats whose tapered ends are directed inward from the mouth to prevent fish from escaping once they enter the net. A fyke net is a hoop net with two wings or leads of webbing attached to the mouth to guide fish into the enclosure. Our hoop nets have large square hoops at the front of the net and taper to a smaller diameter with smaller ring hoops at the back end. Webbing extends inwards and backwards between the sides of the first square hoop to form a "V" slot at the net mouth and a funnel is attached to the back of the second square hoop. The chamber between the funnel and the rear of the net is termed the "pot". The net is tapered at the rear end and held closed with a draw string which can be opened to permit removal of the trapped fish from the pot, although trapped fish may also be present between the "V" slot and the funnel. The funnel also has a draw string which allows removal of fish from this chamber. If it is desirable to have a fyke net, use two lengths of webbing tied to the sides of the hoop net mouth to convert the hoop net to a fyke net.

Fyke nets are typically set at a time and location where fish will be moving through the area in a direction that will lead them into the net mouth. They are very effective when set in small tributaries to lakes or larger rivers during a spawning run but can also be used in shallow areas of lakes and larger rivers. The net and wings are anchored in place by tying them to rebar posts embedded in the substrate. The wings of the net should be set at a 45° to the axis of the hoop net.

As the holding chambers in the fyke nets are small, they should be checked and cleaned of fish on a regular basis, particularly during an active spawning run. Try to set the net so that fish in the holding chamber will not be subjected to high water velocities. Sampling effort is usually recorded as the number of hours between net cleanings. Record fyke net dimensions such as mesh size, mouth size, wing lengths and, when used in streams, whether full or partial channel blockage was achieved and whether the net mouth was oriented upstream or downstream.

3.5.9 Kick Sampling

Kick sampling is used to collect fish eggs from the substrate in spawning areas, both for species which are broadcast spawners and for those which bury their eggs (i.e. from trout redds). It can be used to determine if incubating eggs are present but it is generally considered a qualitative (i.e. non-quantitative) sampling technique and, unlike airlifting, is not suitable for determining the relative density of eggs. The kick sampler is attached to a pole and consists of a tapered net attached to a metal frame which forms the mouth of the net. It is generally used in flowing water. To use, grasp the pole and place the kick net against the substrate. Stand upstream of the net mouth and use your feet to disturb the substrate, letting the disturbed materials float into the net. Remove the net from the water and examine the contents of the net for eggs.

Kick sampling can only be conducted in water shallow enough or which is flowing slow enough to allow instream wading. This technique is simpler to use than the airlift sampler and requires considerably less equipment. It is a very efficient and fast technique for identifying spawning areas in wadable streams, particularly over long lengths of stream.

3.5.10 Minnow Trap

Minnow trapping is a passive sampling technique used to sample for the presence of minnow species and small life stages (i.e. fry) of larger species which can be difficult to capture using other techniques such as electrofishing or gill netting. The traps we use are Gee Minnow Traps which consist of two pieces which are clipped together to form a small cylinder slightly tapered at either end. Each end has a funnel which leads into the centre of the trap which allows fish to enter but prevents them from escaping. The traps are generally placed on the substrate in the shallow shoreline areas of lakes and streams with the long axis of the trap parallel to the shoreline. A length of sideline is used to tie the trap to a stake or anchor on shore to keep it in place. The anchor site is usually flagged so that the site can be easily found when returning to check the trap. The traps can be baited or unbaited, depending on if the intent is to trap fish moving through the area or attract fish to the trap.

Sampling effort is recorded as the number of hours that the trap is set.

3.5.11 Observation

Underwater observation involves the use of either snorkeling or SCUBA techniques to observe, count or record the activities of fish. Scuba diving is generally restricted to lake habitats but may also be employed in deeper rivers. It is a fairly intrusive technique and is considered to be more disruptive than snorkeling and requires that the observer have a valid scuba certificate. Snorkeling is commonly employed by Golder to conduct fish observations in stream habitats which have low turbidities. It is less disruptive than SCUBA and logistically simpler. Equipment used for snorkeling includes a diving mask, snorkel, dry suit, diving gloves and an underwater writing slate. A wet suit can be used in place of a dry suit in warm water but a dry suit is preferable as it increases observation time. To date, snorkeling has been used by Golder to study the habitat preferences of some fish species but the technique can also be used to determine fish abundance and distribution.

3.5.12 Post-Emergent Trap

Post-emergent traps are a passive sampling technique for use in flowing water to sample for the presence of post-emergent fry. Unlike emergent traps which capture the fry as they emerge from the substrate, post-emergent traps capture the fry as they drift downstream following emergence. Unlike emergent traps, it is not required that they be set at a spawning site overtop of incubating eggs, there only needs to be a spawning area somewhere upstream of the set location. Post-emergent traps are essentially extremely large drift nets. Each trap consist of a tapered, small-mesh net attached to a metal frame which forms the trap mouth. The trap mouths are 0.9 x 0.9 m in size. Each net is equipped with a removable sample bottle attached at the downstream end of the net. A post-emergent trap is set by anchoring two rebar poles into the substrate and looping the four hoops attached to the trap over the poles and sliding the trap down until the bottom of the trap sits on top of the substrate with the mouth facing upstream.

Post-emergent traps should be checked at a minimum of twice per day, once in the morning and once in the evening. Definite diurnal/nocturnal patterns have been observed using these traps, so be sure to record the catch separately for each sampling period. To check the catch, remove the trap from the stream and wash all materials from the netting into the sample bottle. Dump the contents of the bottle into a sampling tray to look for the fry. Post-emergent fry are extremely small and almost transparent. They are best seen by looking for the large, dark eyes which will be their most obvious feature. They may also be seen to be swimming around in the sampling tray. It is also prudent to check the mesh of the trap for additional fry as they are so small that some become "gilled" on the mesh and do not wash down into the collection bottle. If more than one species may be hatching at the time and location of your study and you are not sure of the identification of fry in the sample, the sample should be preserved in 5% buffered formalin for laboratory identification.

Sampling effort is recorded as either catch/hr or catch/m^3, as described for fry traps (Section 3.5.6). Post-emergent traps are used to check for the presence of post-emergent fry in the study area, either as proof of spawning activity in upstream areas or simply to tell if this life stage or a certain species is present. They are also used in entrainment studies, which are conducted to determine if fish are entering man-made structures such as diversion canals or water intakes. In addition, they may be used to determine the timing of hatching periods and the relationship between hatching and environmental parameters such as discharge or water temperature.

3.5.13 Seine Netting

Seine netting refers to the use of a specifically designed net to catch fish by dragging it through the water. Seine nets consist of netting suspended between a float line and a lead line. The netting is constructed of thicker net material than gill nets so that fish do not become gilled in the mesh. Mesh sizes vary but most nets are constructed of minnow netting which has a small mesh size and is suitable for catching forage fish and small life stages of larger fish species. Larger mesh seine nets are also available for sampling for large fish and are much easier to drag through the water. Two types of seining operations are possible, beach seining and boat seining.

Beach seining is accomplished by two people dragging the net through the water while wading and is used in shallow water areas in lakes and streams. To beach seine, each person grabs one end of the net by placing one foot in the loop at the end of the lead line and holding the loop at the end of the float line in their hands. One person walks out from shore to a suitable depth. Both people then walk parallel to shore dragging the net between them. The lead line is kept in contact with the substrate to prevent fish from escaping under the net by dragging the foot looped to the lead line along the bottom. As they walk through the water, fish are herded in front of the net. The person near shore moves slower than the person further out. When the further person has passed the near shore person they curve back to shore, meeting the near shore person at the waters edge and bringing the two ends of the net together forming a pen holding the captured fish. Both people then drop the float lines and pick up the lead lines and standing side-by-side pull the net up on shore, ensuring that the lead line remains in contact with the substrate at all times. The trapped fish will congregate in the end of the looped net and will be dragged up onto shore.

Boat seining is a specialized technique used in water too deep to wade. It usually involves the use of long, large mesh seine nets for the capture of large fish. It is particularly useful in areas where fish congregate such as spawning areas of lakes or snye areas in rivers. The principle is similar to beach seining except that a boat is used to move the offshore end of the net through the water. A pole is attached to both the lead and float lines, at the boat end of the net, and is used to keep the lead line on the bottom.

Seine netting is a suitable technique only where the bottom is fairly smooth. If large substrate particles, debris, or aquatic vegetation is present which will cause the lead line to lift off the bottom as it passes, the technique will not be very efficient and most or all fish will escape. Seine netting is typically used to sample for the presence and abundance of small fish and life stages which are not effectively sampled for using other inventory techniques.

Sampling effort is recorded as the number of seine hauls made and either the distance (m) or the area (m^2) seined for each haul. Record the dimensions of the seine net used (length/depth/mesh size) and the shoreline distance of each seine haul. If area is required, multiply the length of the seine haul by the length of the seine net used.

3.5.14 Set (Trot) Line

A set line is a series of leaders and baited hooks strung from one central line which is anchored to shore. Set lines are used to catch predatory fish and are usually set out overnight. Golder set lines are 30 m in length, which includes a 10 m lead with no hooks and 20 m of line with a total of 10 leaders/hooks set at 2 m intervals. A large lead weight is attached to the end of the line to keep it in place once it is set. The 10 m lead is used to set the baited hooks well out from shore or can be tied short to keep the hooks near shore, as desired.

Sampling effort is recorded as the number of hours the line is set or the number of hook-hours if set lines of different lengths and number of hooks are used. Record the size of the hooks that are used (e.g. #8 hooks).

3.5.15 Trap/Counting Fence

Fish traps or counting fences are a passive sampling technique used to capture fish as they move past a specific location. They consist of one or more trap boxes with fences (wings) which stretch out in front of the entrances of the boxes to lead fish into the trap. The trap boxes are large holding pens enclosed on four sides as well as on the bottom with metal or plastic mesh. The front of each box has an opening equipped with a funnel which leads into the interior of the trap box. The boxes are also equipped with locking plywood lids to protect the fish as they congregate in the traps. The fences consist of angular aluminum frames with a series of holes into which are fitted round aluminum rods to form a barrier to fish passage. The counting fence is installed by attaching the components to rebar posts driven into the stream bed and by placing sandbags on cradles included in the fence design. The fences or wings are set as close as possible on a 45° angle to the trap box entrance.

Two types of counting fence set-up are possible, the **one-way fence** and the **two-way fence**. The one-way fence has only one trap box and one set of wings and is used to capture fish moving in one direction. The two way fence has two trap boxes facing in opposite directions, each with its own set of wings, to capture fish moving in both directions. Counting fences can be used to sample portions of the shoreline in lakes or large rivers but are typically used in small or medium sized streams to close off the entire channel and capture all fish moving past the trap location. In this case, the box which captures fish moving upstream is called the upstream trap and the box catching fish moving downstream is called the downstream trap. In streams, the trap boxes should be set in a location where the water velocity is not too high so that the fish caught in the trap can rest. If no such site is available, a piece of plywood placed upstream of the trap will provide a velocity shelter

The counting fence should be checked a minimum of twice a day, once first thing in the morning and once again in the evening and the fish removed from the traps using a dipnet. The fence should also be cleaned of debris to keep the water flowing freely through it and to reduce the build up of pressure on the fence. Record the day, time and catch each time the fence is checked. During an active spawning run, the fence may need to be checked more frequently so that the number of fish holding in the trap boxes does not become too large. Record the catch separately for each sampling period. After removing the fish from the trap boxes they should be released in the direction that they were travelling so that they can continue in that direction (i.e. fish from the upstream trap should be released upstream of the counting fence while fish from the downstream trap should be released downstream of the fence).

Counting fences are used to determine the species, relative abundances and timing of movements of fish past the sampling site. They are typically used to capture fish during their spawning runs in the spring or fall or to quantify the movements of fish into and/or out of tributary streams.

3.6 Catch-Per-Unit-Effort (CPUE)

Catch-Per-Unit-Effort is a measure which relates the catch of fish, with a particular type of gear, to the sampling effort expended; it is expressed as: ***number of fish captured/unit of effort***. Results can be given for a particular species or the entire catch. CPUE is used to define species relative abundance and to compare abundances between sites and/or seasons. Effort can be expressed a number of ways depending on the sampling equipment. If CPUE data is required, sampling effort must be recorded. Following are common CPUE calculations for traditional sampling gear:

• electrofishing (boat and backpack)	No. of fish/100 seconds (of active electrofishing)
• gill net	No. of fish/net-hour, or /panel-hour, or/100m of net-hour
• set line (trot line)	No. of fish/hour, or /hook-hour
• angling	No. of fish/hour, or /angler-hour, or /rod-hour
• minnow trap	No. of fish/hour, or /trap-hour
• seining	No. of fish/area seined (m^2), or /length of shoreline seined (m)
• counting fence (fish trap)	No. of fish/hour
• drift net/post-emergent trap	No. of fish/hour, or /volume of water (m^3)

It is important to recognize the components of the effort inherent in the sampling technique being employed so that effort will be recorded properly. Most field forms will have fields specifically designed to record the pertinent information. Record all aspects of your sampling effort (e.g., number of set lines used and number of hooks per line) so that CPUE can be calculated. CPUE values will be used in our own studies to establish relative abundance. Our data may also be used in a more historical context to compare the abundances we record with past or future research, using both similar and different sampling gear, and CPUE values may need to be recalculated to conform to other studies. The more detailed used when recording sampling effort, the easier it will be to accommodate these needs.

3.7 Coldwater Fish

When dealing with the general suitabilities of freshwater habitats for game fish species, temperature regime is often used to describe the habitat potential and the species assemblage which could possibly be present. Although the terms are not definitive or precise, the designations of habitats as "coldwater" or "coolwater" habitats and the associated fish fauna as "coldwater" or "coolwater" species are often used.

Coldwater fish are those which have a preference for summer water temperatures ranging from about 10-18 °C. In Alberta, this encompasses all of the salmonid species including the trouts, whitefishes and Arctic Grayling. Within this group the species will have differing temperature preferences and tolerances (see section 3.50 - Temperature Criteria).

3.8 Condition Factor (Ponderal Index)

Condition factors are used to describe the plumpness and, by inference, the well-being of individual fish. Formulas are used to calculate condition factors using the fish's length and weight and are based on the principle that the weight of a fish will vary with the cube of its length. Any variation in the shape or plumpness will be measured using the formula. Golder primarily uses the coefficient of condition *K*, also called the Fulton condition factor. The formula (**using metric length and weight data**) is as follows:

$$K = [\text{weight (g)} \times 10^5] / \text{fork length}^3 \text{ (mm)}$$

Condition factor is believed to reflect the nutritional state or well-being of an individual fish. The *K* value will be 1.0 for fish whose weight is equal to the cube of its length. Fish which have a *K* value >1.0 are more plump and are thought to have a higher degree of well-being or better nutritional state-of-health, whereas fish with a value <1.0 are considered to be less robust.

Condition factors vary with season, sex, sexual maturity, age and various other factors. Therefore, if sufficient data is available, average condition factors for a species should be calculated separately for each sex and should exclude young-of-the-year fish. Condition factors also vary by species, particularly if they have different shapes, and should not be used to compare well-being between fish species. They can, however, be used to determine differences in the condition of fish of the same species in different years or at different sites. Fulton's condition factor is also limited for comparisons between fish populations in different lakes because of differences in growth parameters. Other formulas for condition factor calculations are available and would be designated by the project manager if they are required.

3.9 Coolwater Fish

Coolwater fish are those which generally prefer summer water temperatures ranging from about 18-26°C. Alberta species generally considered to belong to this group include northern pike, walleye, sauger, yellow perch, goldeye, mooneye and lake sturgeon (see also Section 3.7 - Coldwater Fish).

3.10 Creel Census

The term "creel" refers to the basket a fisherman uses to hold the fish which have been angled and a creel census refers to a survey in which recreational fisherman are censused in order to determine aspects of the recreational fishery. Important survey goals typically include determining angler effort and success (i.e. fishing pressure and harvest) and may include examining the fisherman's catch for tagged fish or to collect ageing structures.

3.11 Dissolved Oxygen Criteria

The dissolved oxygen concentration in the water is an important habitat component. Different fish species have different dissolved oxygen requirements and have different tolerances to low dissolved oxygen levels. Dissolved oxygen criteria provide minimum dissolved oxygen levels that are necessary to protect various life stages and have been developed for selected game fish species. Golder has prepared a document which list the criteria for selected Alberta species (Taylor and Barton 1992).

3.12 Fecundity

The most common measure of reproductive potential in fish. Female reproductive potential is the total number of eggs (ova) in both ovaries of a gravid female fish. Fecundity normally increases with the size of the female within a given species. For most studies conducted by Golder, fecundity is determined for female fish only. Fecundity is determined by recording the total weight (g) of both ovaries and removing a small sub-sample of known weight from the middle of the ovaries (usually a 1.0 g sample). Count the number of eggs in the sub-sample to determine the number of eggs/g of ovary. Multiply this value by the total ovary weight to calculate the total number of eggs.

3.13 Field Forms

Golder uses a number of specially designed field forms to aid in recording field data. They are not meant to replace the use of a field book or the recording of detailed field notes. They are intended to provide a template showing the type of supporting data that must be recorded for each sampling technique and provide an organized method of recording the sampling results. For each specific or general type of sampling technique there is a ***Catch Record Form*** (e.g. Gill Net Catch Record Form) for recording sampling information such as location, technique, effort and is used to summarize the results. The main form for recording the catch results is the ***Fish Sample Record Form*** which has fields for recording length and weight data and other particulars for each individual fish. On the back of this form you will find a list of all abbreviations to be used when recording data.

A copy of each field form is kept in the aquatics reference file located at Carole Collins desk (Aquatic Ecology Group Secretary). Copy the forms you will require onto waterproof paper and return the originals to the file.

3.14 Fish Collection Licence

Fish collection licences or permits are granted by provincial governments or by DFO and are required for all fisheries sampling activities. Obtaining a license varies from province to province. In Alberta, a Fish Collection Licence is granted to Golder by Alberta Environmental Protection, Fisheries Management Division. Each Licence is specific to the waterbody(s) being sampled and is valid for a specified time period. To obtain a Licence you must forward a letter of request to the F & W District office for the region in which you wish to sample. Include in the letter the reason for sampling, the location(s) to be sampled, the period the permit should be valid for, the capture techniques to be employed, the fate of the fish captured (i.e. will any be sacrificed), and the personnel to conduct the sampling. They will then send a Licence granting permission to carried out the proposed activities. They may impose specific restrictions on the licence (i.e., restricted number of fish allowed to be sacrificed, designation of a certain landfill for fish disposal, or specific reporting requirements) and the permits should be read carefully to ensure all restrictions will be followed. The original permit or licence should be immediately placed in the project file and a copy of the document given to the field personnel. You must be prepared to produce a copy of the permit while conducting any field sampling.

The Fish Collection Licence will also specify a date by which a permit return is to be submitted to the issuer. In Alberta, the permit return is a form which accompanies the Licence. The form requests information regarding the sampling conducted under authority of the Licence, such as sampling locations and results. Fill out the form and send it to the office which issued the Collection Permit following completion of sampling activities and prior to the date specified on the Licence.

3.15 Forage Fish

A general term applied to smaller species of fish that “forage” on small invertebrate animals or plant materials. This includes minnow species and other small fish such as sculpins, stickleback, trout-perch and darters.

3.16 Game (Sport) Fish

Fish used by anglers for recreational fishing or sought after by the commercial fishing industry, e.g., northern pike, walleye, trout, etc.

3.17 Geographical Position

All sampling sites, whether they are point locations (such as a minnow trap site) or sections (such as a section of river that was electrofished), should be recorded on a map of the study area. The standard is to use a 1:50,000 NTS topographical map but other maps or airphotos can be used if they provide greater detail. The geographical position of sampling sites can also be recorded using Universal Transverse Mercator (UTM) grid coordinates or by degrees of latitude/longitude. UTM coordinates are particularly useful in case the map is lost as they can be used to pinpoint the sampling site on a new map.

UTM and latitude/longitude are two different systems of grid coordinates used to establish geographical location. Both systems appear in the margins of 1:50,000 scale National Topographical Service maps. A calibrated ruler is used to calculate coordinates of any point on the mapsheet. Golder always uses UTM coordinates rather than lat/long, unless otherwise specified by the client.

The most accurate way to record the position of the sampling site is to use Geographical Position System (GPS) technology. If possible, use a GPS rover unit to record a position file at the sampling site that can be stored for differential correction. You should also use the GPS unit to record a “real-time” waypoint in the event that the stored file is lost or accidentally deleted. If you do not have a GPS unit capable of differential correction, a simpler unit will allow you to record a waypoint, which will be less accurate.

3.18 Gradient

Gradient refers to the vertical drop in elevation along a watercourse over a horizontal distance. It is recorded as the percent gradient. To determine the gradient over a length of stream, measurements are taken off of a 1:50,000 scale NTS map of the watercourse. Locate a point upstream and downstream of the study area on the map where contour lines cross the stream and determine the difference in elevation (m) between these two points. Measure the distance (m), following the channel, between the same two points using a map wheel. The gradient is calculated as follows:

gradient (%) = [difference in elevation (m)/distance (m)] x 100

In very flat terrain determining gradient from a map may not be possible. In these situations, gradient may also be measured in the field using a clinometer. With this method one person with a clinometer stands at the upstream end of the section to be measured, a second person moves as far downstream as possible while still visible to the upstream person. Both individuals stand at the very edge of the stream with their feet at the water surface. The upstream person uses the clinometer to measure the angle from his or her eyes to the eyes of the other person. If your clinometer measures in % then this value should be recorded. If the clinometer measures in degrees, then percent can be calculated by taking the tangent of that number and multiplying by 100. This technique may need to be repeated several times and averaged to determine the gradient of a large section of stream.

3.19 Growth

Fish show indeterminate growth in that they continue to grow throughout their lives rather than stop growing once they reach an "adult size". However, growth rate is asymptotic, meaning the growth rate decreases with increasing age approaching some maximum value for the individual or population. As growth rate is a function of time, true growth rates can only be determined when fish length and age is known. Two parameters related to growth rate are: 1) the maximum size which is possible for fish in a given population, and; 2) the rate at which maximum size is achieved. The maximum size value indicates whether the population is "stunted" (i.e. does not have the potential to reach the normal maximum size for the species) and differentiates between populations that are stunted and those which do not achieve their potential maximum due to a short life span. If the maximum size for the population is at the lower end of the normal range for the species, than the population is slow growing rather than stunted. See Mackay et al. (1990) for methods of calculating maximum size and rate.

3.20 Gonads

Organs which are responsible for producing haploid reproductive cells in multicellular animals. In the male, these are the testes and in the female, the ovaries. In fish they are located in the peritoneal cavity, extending between the diaphragm and the cloaca, and running along the dorsal side of the cavity along both sides of the spine. When the fish is gravid, the gonads will fill much of the peritoneal cavity.

3.21 GSI (Gonadal:Somatic Index)

Gonad-Somatic Index is the proportion of reproductive tissue in the body of a fish to total body weight. It is calculated by dividing the total weight (g) of the gonads by the total body weight (before gonad removal) and multiplying the result by 100. It is used as an index of the proportion of growth allocated to reproductive tissues in relation to somatic growth. It is believed to be an indicator of fish health in that a fish with a comparatively low GSI for its species is considered to not have sufficient energy available for proper gonad growth. Fish are seasonal spawners and the size of the gonads changes dramatically as they pass through the various stages of gamete maturation. It is preferable to conduct GSI measurements for fish just prior to the spawning season when the gonads are fully developed (i.e. gravid).

3.22 Habitat

Fish habitat refers to aspects of the physical environment which provide the requirements of a fish community, species or life stage. Habitat evaluations conducted for fisheries studies generally involve measurements or evaluations of macro- and/or micro-habitat conditions in order to determine the types of fish or life stages an area might support, the quality of available habitats or habitat limitations.

Macro-habitat

Macro-habitat refers to habitat components which are attributable to a general region or section of the study area. They are general conditions related to geographical location, climate, stream order, lake type, etc. For macro-habitat evaluations, we typically measure general water quality parameters (dissolved oxygen, temperature regime, pH, conductivity, turbidity, visibility (secchi depth), stream gradient), as they relate to describing coldwater and coolwater habitats and the types of fish species which may be present. Different fish species have different tolerances for macro-habitat conditions which affect their abundances and distribution.

Micro-habitat

Micro-habitat conditions are the physical conditions at a specific location. For micro-habitat assessments we measure or evaluate water depth, velocity, substrate particle size and condition, and the availability of cover for fish. Cover includes instream cover (i.e. any objects which provide velocity shelters) and overhead cover (i.e. anything which provides visual isolation). Each fish species has a range of micro-habitat conditions which are suitable, ranging from barely useable to optimal. In addition, each species has a series of life stages which may also have different habitat requirements. These life stages include spawning, incubation/embryo, nursery, rearing, feeding (adult summer) and overwintering.

Knowledge of the suitable and preferred habitat conditions for different species and life stages is very useful when conducting fisheries inventories, habitat evaluations and impact assessments. Information concerning these habitat requirements is available in the form of Habitat Suitability Index (HSI) models and Habitat Preference Criteria (HPC). HSI models were developed by the U.S. Fish and Wildlife Service and are species-specific models, with each model containing information for all life stages of one fish species. The models include all the habitat variables (macro- and micro-habitat) that accumulated research has determined to be significant to each species with respect to population abundance. Each habitat variable is provided along with the range of suitable and optimal conditions. HPC are species-specific curves showing suitable and preferred conditions for micro-habitat variables (depth, velocity, substrate and cover). HPC curves are available for a limited number of game fish species and were developed from snorkeling observations of the different species and life stages (developed for the most part by Golder from streams in Alberta).

Measurements of macro- and micro-habitat conditions in lakes and streams are useful in combination with inventory data and existing information to establish habitat potential for a study area. Habitat based assessments are being used more frequently to provide a complete picture of habitat potential, with respect to use by different fish species and life stages, rather than relying on fish inventory data from a specific point in time.

3.23 Length

Refers to the whole body length of a fish. There are three types of length measurements: standard length, fork length, and total length. The measurement most commonly used in Canada and ***required for use by Golder*** is the ***Fork Length*** and is ***always recorded in millimetres (mm)***. Fork length is the distance from the most anterior point on the head to the tip of the median caudal fin rays. The fork length of captured fish is measured on a fork length board, which is a trough or flat board with a ruler attached to the surface and a vertical block at the anterior (zero mm) end. Place the fish on the board with its head flush with the block and spread the caudal fin to show the mm mark under the anterior point of the fork.

Some fish species such as burbot, sculpins and darters do not have a fork in their caudal fins. For these species, the standard measurement is Total Length, which is the distance from the most anterior part of the head to the distal tip of the longest caudal fin ray.

The fish which must be measured for length and weight may vary between projects. You will always be measuring game species but will not necessarily have to measure rough or forage fish. The project manager will be able to tell you what is required. For instances where large numbers of individuals are being captured and the time required to measure length and weight is excessive, it may be possible to measure length only for some fish. A large number of lengths are required to produce a complete length-frequency distribution (see section 3.25) while a lesser number of weight measurements are required to provide an accurate length-weight analysis (see section 3.26). If fish are being preserved, always measure length and weight before preserving.

3.24 Length-at-Age

Length-at-age analysis is used to determine the average length of fish in each age class in the population. This analysis can only be conducted for individuals for which age is known. For each age class (i.e. 1 year old fish, 2 year old fish, etc.) calculate the range of lengths, mean length and the standard deviation of the mean. Plot this data graphically showing the range, mean and standard error (error bars) (see section 3.47 standard error and standard deviation) with age as the X-axis.

3.25 Length-Frequency Analysis

Length and weight data provide the statistics that are the cornerstone of fisheries research and management. Rate of change of length in individuals and length-frequency distributions are key attributes of fish populations. Length-frequency analyses provide an important description of population structure and are used to provide information for the interpretation of age and growth, especially for young fish. Length-frequency distributions reflect the interaction of rates of reproduction, growth and mortality of the population. However, when interpreting length-frequency data it is important to evaluate sampling biases for the capture technique that was used, particularly with respect to size selectivity. The length-frequency distribution of a population is shown graphically by plotting the number of fish in each size class using a histogram chart. Typically, size classes include every 50 mm fork length interval (i.e. 0-50 mm, 51-100 mm, 101-150 mm..... etc.) but may be more frequent if you have a large sample size. When plotting the length-frequency distribution using Microsoft Excel, label the size classes on the X-axis of the graph using the complete label (i.e. 0-50 mm, not 50 mm).

Using the length-frequency analysis to determine fish age and growth rates is called the Peterson method. The plot of the length-frequency analysis is examined for peaks which are believed to represent each of the year classes in the population. The peak closest to the Y-axis would represent zero aged fish (young-of-the-year) and each peak after that should represent another year class. Great care must be exercised when conducting age analysis with this technique. Typically, distinct peaks are only evident for the first few year-classes. Individual fish exhibit different growth rates and as they get older, the overlap in size ranges for each age class becomes too great and the peaks in the length-frequency distribution are lost. In addition, this method requires measurement of a large number of fish which represent an unbiased sample of the population. The size intervals (fork length classes) chosen for plotting these data are particularly important, as size intervals which are too large or too small will obscure the peaks. Other problems with this method include dominant year-classes which may obscure the peaks of weaker year-classes and divergent growth rates of male and female fish complicates the analysis as does the small incremental changes in length which occur in older fish. However, the Peterson method is quite suitable for some forage fish populations where the life-span is short. It is the recommended ageing method for some minnow species which may have life-spans as short as three years.

3.26 Length-Weight Relationships

Length-weight relationships can be used in order to assess the state of well-being of a fish population. These relationships can be used to compare the condition or "fatness" of fish in a population to other populations, or to that in previous years. As a fish population size increases and/or food resources decline, individual fish become thinner and the ratio of weight to length decreases.

The relationship between fish length and body weight is curvilinear, and can normally be represented by the following function:

$$W = aL^{b}$$

where W = weight, L = length, and 'a' and 'b' are constants which are characteristic of the population being examined. The constant 'b' reflects the rotundness of the fish or the rate at which weight increases for a given increase in length. In general, a value of 'b' less than 3.0 represents fish becoming less rotund as length increases, and 'b' greater than 3.0 indicates a population where fish become more rotund as length increases. If 'b' is equal to 3.0, growth is isometric, meaning shape does not change as fish grow.

The length-weight relationship that we typically use is called length-weight regression analysis. The length-weight relationship can be changed from curvilinear to linear (straight line) using a $\log_{10}$ transformation of both length and weight. The relationship between length and weight becomes:

$$\log W = \log a + b \log L$$

where log a is the 'Y' intercept of the regression line and b is the slope of the line. A regression analysis can be conducted from length and weight measurements of a sub-sample of the fish population. Be sure to measure fish which are representative of the size range in the population, that is an even number of fish should be measured from all size groups in the population, from the smallest to the largest fish. A general rule is that at least 30 fish should be measured to provide a large enough sample size to calculate an accurate regression. The regression analysis plots the log weight versus log length for all the fish measured and then produces the "best fit" straight line that approximates the mathematical relationship between length and weight. The regression analysis can be conducted by entering the length-weight data on a computer spread sheet (Microsoft Excel) and having the program conduct the log transformation of the data. The computer program will provide the regression equation, including the values for 'a' and 'b'. When conducting a regression analysis, you should also record the 'R' value (coefficient of determination) that the computer calculates as this value represents properties of the linear relationship. The higher the 'R' value, the more closely the data conforms to a straight line and the better the regression equations represents the data.

Differences often exist in the body weight to length relationship for males and females in the same population. If possible, length-weight regressions should be calculated separately for the two sexes. The relationship also changes throughout the annual growing season, particularly for females, as gonad size and weight increases, so care should be taken when comparing various sets of data. Prior to conducting a length-weight regression analysis, the length-weight data should be plotted on a scatter diagram in order to spot 'outlying' data points. Points which are well outside the range represented by the other data points should be checked for accuracy to make sure both length and weight were recorded properly.

3.27 Lesion

Lesions are the result of a pathological change in body tissue. External hemorrhagic lesions (bloody sores) may be observed on the body surface of the fish and should be recorded on the Fish Sample Record form. Reddened areas and lesions on the body surface are evidence of systemic (widespread, internal) infections of bacteria or superficial bacterial infections. Skin lesions in wild fish are seen most often in the early spring when rising water temperatures encourage bacterial growth at a time when fish are least resistant to it. An increased prevalence of skin lesions also has been associated with fish from water with a high organic load and bacterial community, such as below a sewage outfall.

3.28 LSI (Liver:Somatic Index)

Liver-Somatic Index is also known as hepato:somatic index. It is the ratio of liver weight (g) versus total body weight, expressed as a percentage of total body weight. The LSI is used as an indicator of fish health. Energy is stored in the liver in the form of glycogen and the relative size of the liver is believed to correlate with nutritional state.

3.29 Marking/Tagging

Identification of individual fish or simply identification of fish which have been captured is required for some projects. Different marking techniques are available, depending on the goals of the study.

3.29.1 Anchor (Floy) Tagging

A practical and inexpensive method of permanently marking individual fish. The tag, shaped like an inverted "T", is most commonly inserted through the fishes' back at the base of the rear portion of the dorsal fin and anchored between the epipleural bones of the dorsal fin using a special tag-gun. The tip of the gun is a hollow needle which is inserted through the skin and muscle. As the handle of the tag-gun is depressed, an injector rod pushes the anchor portion of the tag out the end of the gun through the needle. The tag-gun needle will not pass through fish scales. In order to insert the needle, use the tip of the needle to lift the posterior edge of a scale and slip it in under the scale. Fully insert the needle through the skin by inserting it to the base of the needle and depress the handle. Once the tag-gun handle has been fully depressed, hold it in the depressed position while giving the gun a quarter turn to free the tag from the needle. Still with the handle depressed, remove the tag-gun needle from the fish and the tag will remain anchored in place.

The posterior portion of the Floy tag remains outside the fishes' body and is usually brightly coloured and carries a numeric identification code. This tagging method is used when conducting mark-recapture population estimates and basic fish movement studies. It is also the preferred marking technique when seeking angler return data to aid in establishing fish movements. Tags marked with the researchers address and the phrase "$2 reward" are often used to ensure angler response.

When sampling, always record the recapture of marked fish, even if the tag is not one that was inserted during your present study. It is common to catch fish carrying old Floy tags inserted by other agencies who will provide the date and location the fish was tagged; information which will provide movement data for all of the researchers involved. Older tags will usually have a build up of algae and will need to be scraped clean with a knife in order to read the tag number and other information.

Floy tags will usually carry the name and address of the client/agency that Golder is working for and, therefore, the tags are usually provided by the client. If this is not the case, Floy tags will need to be ordered and discussion with the client may be necessary to decide what writing the tags will carry.

3.29.2 Visual Implant (VI) Tagging

A "micro-tag" method using tags which are inserted under the skin. VI tags are suitable for use when a tagging method is required which has minimal effects on the swimming and feeding efficiency of the fish. Good for tagging smaller fish than is possible with the anchor tag method, such as small fish species or juvenile fish. Each tag consists of a small metal strip with an individual alpha-numeric code (typically three digits) which is inserted using an injector into a clear tissue somewhere on the fishes body (e.g., post-ocular tissue for salmonids). If working with non-salmonids, it will be necessary to determine a suitable implant location for the fish species you are working with. The implant location should have a sufficiently thick layer of clear tissue so that there will be room to insert the flat injector needle and the tag can be read through the tissue. Record in the field notes the location (including left or right side) of tag insertion for each fish species that you are tagging. To tag a fish, insert the injector needle into the selected tissue, depress the injector and hold it down while removing the needle from the fish.

3.29.3 Batch Marking

A marking method which does not distinguish between individual fish. Common methods are fin clipping or dye marking. Batch marking can be used to distinguish fish from specific sites by varying the location on the fishes' body which is dye marked, the colour of the dye or varying which fin is clipped by sampling site. This method is suitable for simple movement studies and for simple mark-recapture population estimates. This method is also used when extremely large numbers of fish need to be marked, as it is simple and more economical than anchor or VI tagging.

Dye marking is accomplished by injecting a small amount of a coloured dye or liquid plastic sub-cutaneously. It can be used for marking very small fish, such as minnows and other forage fish, since a very small hypodermic needle can be used as the injector. One disadvantage of dye marking forage fish is that it is difficult to avoid using a colour which is readily visible to the researcher without increasing the probability of predation of the marked individuals.

Fin clipping includes removing or distinctively altering a fin in a recognizable manor. Fin removal is usually only conducted for non-essential fins such as the adipose fin on salmonids. For other fins such as the pectoral or pelvic fins, the first two fin rays may be removed. For larger fish, a hole punch can be used to make a distinctive mark on a fin. When clipping a fin, it is important to make straight, regular cuts to distinguish the mark from naturally frayed or eroded fins. Record the fin which is marked for each sampling site.

3.29.4 Radio Tagging

Attachment of a battery powered radio transmitter to a fish in order to follow its movements using a radio telemetry receiver. The transmitter is affixed externally or surgically implanted in the body cavity. To avoid adverse effects on swimming ability, the transmitter should be <2% of the fishes' body weight. Ground, boat or aerial surveys are conducted with the telemetry receiver in order to follow the fishes movements.

3.30 Maturity (State-of-Maturity)

Maturity refers to the state of gonad maturation of an individual fish at the time it is examined. It does not refer to whether or not the fish is "mature" (i.e. adult); classification of a fish as juvenile or adult is referred to as life-history stage (see Section 3.46).

For adult fish, the gonads will typically progress through a series of conditions or phases of maturation each year during the seasonal development cycle. Although juvenile fish have only one possible state-of-maturity, adult fish can be one of several maturities. The state-of-maturity is used to determine the current reproductive status of the individual. For fish populations, state-of-maturity data can be used to determine the size or age at first spawning, the proportion of the stock that is reproductively active, or to illustrate the nature of the reproductive cycle.

Golder uses a system that includes **9 maturity categories**. The 9 categories, their definitions and abbreviation codes are presented on the back of the Fish Sample Record forms used to record the data. More detailed definitions and descriptions of each maturity category, for both males and females, are provided in Appendix I. Maturity is best determined by conducting an internal examination of the gonads, which requires sacrificing the fish. Maturity can sometimes be determined by external examination of the fish based on fish size and by knowing the typical spawning period for the fish in relation to the capture date or, for some species, by external secondary sexual characteristics which become pronounced during the spawning season (see Section 3.41). The classification system includes an "unknown" category for fish which are examined externally and for which maturity cannot be determined.

For many studies, most or all fish will be released live and only external examinations will be conducted. For other studies, a sub-sample of fish captured will be sacrificed for definitive state-of-maturity data. The following are some hints for establishing state-of maturity from external examination. *Pre-spawning* fish will be found immediately prior to the species spawning season. Fish of a size large enough to be adult or displaying secondary sexual characteristics at this time and with a strongly distended body cavity may be *Pre-spawning*. During the spawning season, gametes (milt or roe) can be extruded from the fish with gentle pressure on the abdomen and it will be obvious that the fish is *Ripe*. *Spent* female fish can be identified by a flaccid, concave abdomen resulting from shedding of the large egg mass and abdominal abrasions obtained during spawning activity. They may extrude a small number of residual eggs in response to pressure on the abdomen. *Spent* males may also have abdominal abrasions and will probably still extrude milt with abdominal pressure, but the milt may appear "watery". Other maturity classifications are very difficult to determine from external examination.

3.31 Milt

Milt is a milky white fluid extruded by male fish during spawning activity and contains the sperm. During spawning season, ripe male fish will extrude milt in response to pressure on the abdomen.

3.32 Necrosis

The death of a tissue due to injury or disease.

3.33 Parasites

Fish are subject to several types of internal and external parasites. A complete parasitological examination requires sacrificing of the subject and microscopic examination of some tissues. For general fisheries inventories, the occurrence of macro-parasites which can be readily observed by the an-aided eye should be recorded on the Fish Sample Record Form. A basic external examination is conducted while measurements of length and weight are conducted. An internal examination is conducted for fish which have been sacrificed. Common external parasites include body lice, gill lice, leeches and lamprey. Common internal parasites include tapeworms, nematodes and flukes associated with the gastro-intestinal tract and other internal organs.

3.34 Pathology

For fisheries inventory studies, pathology refers to the field examination of captured fish for indications of parasites, disease and abnormalities, without the use of special procedures (e.g. tissue collection) or tools (e.g. microscope). This can include either external pathology or external and internal pathology.

External Pathology

Examination of the body surface, fins, eyes, gills and gill chamber for signs of parasites, disease or abnormalities (deformations). Components of the external examination include body form, body surface, lips and jaws, snout, barbels, opercles, isthmus, eyes, fins, gills, pseudobranch, branchial cavity, anus, and the urogenital opening. A basic external examination can be conducted for most fish while measurements of length and weight are being conducted and the results recorded on the Fish Sample Record Form.

Internal Pathology

Examination of the body cavity and internal organs for signs of parasites, disease and abnormalities. Components of the internal examination include body cavity, mesenteric fat, liver, gall bladder, hind gut, stomach, pyloric caeca, intestines, spleen, gas bladder, kidney, gonads, and muscle. A basic internal examination can be conducted for fish which have been sacrificed.

3.35 Population Estimates

Population estimates are used to determine or approximate the total number of fish, for one species or a number of species, within a study area. Population estimates may be calculated for a portion of a waterbody (e.g. a section of stream - #fish/km) or an entire waterbody (e.g. a lake - #fish/ha). Two basic types of population estimates are used; Removal and Mark-Recapture.

Removal (Reference - Armour et al. 1983)

Removal population estimates involve the isolation of the study area using a physical barrier to block fish movements followed by the removal of fish from the area to provide a population estimate. This technique is restricted to study areas which can be isolated and is typically used in small streams. Small-mesh blocking nets are placed at the upstream and downstream boundaries of the study area to prevent immigration or emigration of fish from the study area. Long minnow seine nets are used as blocking nets and are held in place using rebar posts embedded in the substrate. Care must be taken to ensure the bottom of the net remains in contact with the stream substrate to form an effective barrier.

Electrofishing is used as the capture technique, typically backpack or portable boat electrofishing, depending on stream size and water depth. It is vital that the capture technique be very efficient. If the stream is too deep or wide for effective sampling by backpack electrofishing, the portable boat electrofisher should be used or use two backpack units working simultaneously. Multiple electrofishing passes are conducted within the study area and the catch (species and length) and sampling effort are recorded for each pass. Captured fish are retained in a holding pen or are released outside the study area. The catch will decline with each pass as the number of fish in the study area is reduced. Ideally, the catch on the final pass will be zero as total removal is achieved, however, total removal is not required. What is required is that the capture efficiency must be high enough that the probability of capture for each individual is high. When this requirement is met, most of the fish in the study area will be captured on the first pass. After two electrofishing passes, the capture probability is calculated (Armour et al. 1983). If the capture probability is 0.8 or greater, the capture efficiency is high enough to provide an accurate population estimate and a sufficient number of passes has been conducted. In practice, capture probabilities as high as 0.8 are uncommon and additional passes must be conducted. Typically, 3 or 4 passes must be conducted to get a good estimate of capture efficiency and to get enough data to calculate a population estimate. If after 4 passes the number of fish being captured has not declined to near zero, the sampling technique is not sufficiently effective and the population estimate will have poor accuracy. A population estimate can be calculated from such data, but the confidence intervals will be very large.

It is very important that the diminishing catch on subsequent passes be due to the reduced number of fish in the study area and not to a reduced amount of sampling effort. It is vital that a similar effort be expended on all passes. The number of seconds of electrofishing and the search pattern in the study area should be similar for all passes. Monitor the electrofishing seconds throughout each pass in order to ensure this requirement is met.

If total removal is achieved, the population estimate for each species is equal to the total number of individuals captured. If total removal is not achieved, formulas are used to calculate the population estimate. Two formulas are available; the first is a simple formula for computations for two removal passes and the second is more complex for computations for more than two removal passes (Armour et al. 1983). Both of these formulas are presented on a Microsoft Excel spreadsheet in the G:\Aquatics directory. Simply type in your data for each species (i.e. number of fish captured on each pass) and the spreadsheet will calculate capture probability, population estimate, standard error and the 95% confidence interval. The lower limit for the 95% confidence interval is sometime lower than the number of fish that was captured. If this is the case, the lower limit should be changed to equal the number of fish captured as this number represents the minimum population size.

Mark-Recapture

Mark-recapture population estimates are used in situations where isolation of the study area is not possible or for situations where removal of a significant portion of the population is not practical. Using this technique, a sub-population of fish is captured, marked and released. These fish are then allowed to mix with the larger unmarked population. A sub-sample of fish is then captured and the number of marked and unmarked fish is used to determine the proportion of the total population represented by the marked sub-population. As the size of the marked sub-population is known, the size of the total population can be calculated. This technique is useful in large and intermediate sized streams and in lakes. Any sampling technique with good sampling efficiency can be used but is typically limited to electrofishing, particularly in flowing waters. The mark-recapture technique assumes a closed population (no immigration/emigration) which is not usually true in many situations. Study design should include aspects to reduce the effects of immigration/emigration of fish. For size selective sampling techniques such as electrofishing, population estimates should be conducted separately for different size classes.

For most mark-recapture population estimates, it is recommended that multiple sampling passes be conducted to capture and mark fish. This is followed by a few days without sampling to allow mixing of marked fish in the general population. A sampling pass (census) is then conducted to determine the portion of marked to unmarked fish in the census sample. Batch marking (see section 3.29) can be used for this technique. The population estimate is calculated using the Chapman modification of the Peterson method (Ricker 1975) as follows:

$$N = (M+1)\,(C+1)\,/\,R+1$$

where N = population estimate, M = number of marked fish, C = sample taken for census, and R = number of marked fish in the census sample.

At Golder we generally use the ***CAPTURE*** program (Otis et al. 1978) for mark-recapture population estimates. For this method, the fish marking technique must be Floy or VI tagging (see section 3.29) as each individual fish must be identifiable. Multiple sampling events are conducted in order to tag fish and to keep daily counts of the number of tagged and untagged fish that are captured. The results are then arranged in a matrix which has one line for each individual fish that was captured, along with the day or days it was captured/tagged and recaptured. This matrix is used by the CAPTURE software to provide the population estimate. The CAPTURE program is located in the G:\Aquatics directory. The CAPTURE software tracks the capture/recapture history for each individual fish over each pass and calculates the population estimate based on these results. This technique is believed to provide a more accurate result than the single census-pass estimate presented above. This technique does not require a rest period between the marking passes and a census pass and is more suitable for use in open populations where fish movements in or out of the study area may occur.

3.36 Riparian

With respect to fisheries habitat evaluations, riparian areas are terrestrial habitats bordering water bodies (lakes and streams). Riparian areas are not included within the boundaries of the waterbody but are significant in providing habitat features such as overhanging vegetation, inputs of large-woody-debris, sediment stabilization, shading, moderation of surface water run-off, nutrient inputs, etc. Riparian conditions, including species of bank vegetation and floodplain vegetation when possible, are an important part of habitat evaluations.

3.37 Roe

Fully developed, unfertilized eggs produced in the ovaries of adult female fish. During spawning season, ripe female fish will extrude roe in response to pressure on the abdomen.

3.38 Rough Fish

Large fish species (i.e. non-forage fish) which are not included as game fish. Primarily sucker species.

3.39 Sacrifice

Fish which are killed in order to allow internal examination or collection of ageing structures are referred to as sacrificed. For each fish captured, information on whether or not the fish was sacrificed is recorded on the Fish Sample Record Form (i.e. capture code), which helps to identify fish which have been examined internally versus those which were only examined externally. Fish which are sampling mortalities (accidentally killed as a result of capture) are also recorded as sacrificed. Even if intentionally sacrificing fish is not a part of the study design, dead fish should be examined internally for definitive sex and state-of-maturity data, as well as stomach contents and internal pathology when time allows.

3.40 Sampling Bias

Sample inaccuracy caused by bias or imprecision in sampling; e.g., bias towards large fish because of the type of sampling gear. In statistics, a sampling bias may be represented as skewedness or as variance.

3.41 Sex

Sex refers to the sex of the individual fish, usually recorded as either male or female. However, since determination of sex may be difficult from external examination or from internal examination of juvenile fish, sex may also be recorded as unknown.

Sex Determination (Lethal)

To determine the sex of a fish, an incision should be made on the ventral surface of the body from a point immediately anterior of the anus toward the head to a point immediately posterior to the pelvic fins exposing the gonads. If necessary, a second incision may be made on the left side of the fish from the initial point of the first incision toward the dorsal fin. To observe the gonads, fold back the tissue. Ovaries appear whitish to greenish to orange and have a granular texture. The eggs will be readily apparent in developed ovaries. Testes appear creamy white and have a smooth texture.

Sex Determination (Non-Lethal)

Determination of sex from external examination of the fish is generally more difficult. For some species, sex may be determined from external secondary sexual characteristics, observable either during the spawning season or, for some species, at any time of year. For most fish species, sex of adult fish can be determined during the spawning season by forcing extrusion of the sexual product (milt/roe).

Secondary sexual characteristics are external physical characteristics displayed by fish which distinguish sex. Some species do not display secondary sexual characteristics. Other species show secondary sexual characteristics during the spawning season and these characteristics are only useful for distinguishing sex for adult fish during the spawning season. Still other species have morphological differences which allow determination of sex from external examination at any time.

Mountain whitefish develop small tubercles (raised bumps) on the lateral scales prior to spawning. These tubercles are generally more pronounced in males than in females but, alone, tubercles may not be a reliable indicator of sex. Trout may show differences in jaw morphology with females having a rounded jaw and male developing a kype (extended, upwardly hooked lower jaw). This characteristic is not reliable in that the male may not develop a kype, particularly in smaller adults. Males for most sucker species develop obvious tubercles which show as hard nodules in the pelvic, lower caudal and, particularly, the anal fin during the spawning season and which are very reliable for determining sex in adult fish. Many species, such as minnows, suckers and some trout develop distinct body coloration or markings during the spawning season which may aid in separating the sexes. Two species, goldeye and mooneye, show a difference in anal fin structure between mature male and female fish which is a reliable external indication to distinguish sex at any time. In the female, the longest rays of the anal fin are the first four and all of the anal fin rays are slender. The overall shape of the fin is "smoothly concave". The first half of the anal fin of the male has long rays followed by much shorter rays at the back, giving the fin a "lobed" appearance. In the male, the anterior rays are thick near the base. This characteristic is not reliable for juvenile fish.

3.42 Spawning Surveys

Spawning surveys refer to the visual observation of spawning activity or sampling for the presence of incubating eggs and are used to determine if a site has been used as a spawning area, to determine the distribution of spawning sites within a study area, or to collect micro-habitat data (Habitat Preference Criteria) at known spawning areas. Spawning occurs when eggs (roe) and milt (sperm) are extruded by the fish so as to mix and produce fertilized ovum. This is accomplished in a number of ways by different species. Most game fish species for which spawning surveys are typically conducted are either spring or fall spawning species. There are two basic types of spawning surveys (***egg surveys or redd surveys***) depending on the spawning strategy of the species involved.

Egg Surveys

Some species, such as mountain whitefish, lake whitefish, lake trout, walleye and sauger are ***broadcast spawners*** which distribute their eggs over the substrate in areas of suitable depth, velocity and substrate type. The eggs fall into the interstitial spaces (crevices) in the substrate to incubate, although some species will spawn over hard sand if rocky substrates are not available. Spawning surveys for broadcast spawners are conducted using kick sampling and/or airlift sampling techniques (see sections 3.5.1 and 3.5.9). If the study area is small, systematic sampling can be used to examine the entire area for eggs. In large study areas where this type of sampling is impractical, sampling is conducted by examining areas of suitable spawning habitat for the target species. Habitat preference information (see section 3.22) is used to determine the habitat types that should be examined. The section of the stream or portion of lake that is examined during the survey and the location of all spawning sites where incubating eggs are recovered should be identified on maps of the study area. The standard is to use 1:50,000 scale topographical maps but other maps or air photos may be used if they provide greater accuracy. The number of eggs recovered is also recorded for each spawning site and, depending on the sampling technique, sampling effort may also be recorded at each site.

If incubating eggs are found in a study area where more than one species may be spawning, measure egg diameter for the recovered eggs and use egg size, colour and features such as the presence or absence of oil globules to identify the eggs. Egg diameter can be measured using an egg measuring trough. Place 10 eggs in the trough and measure the total amount of the ruler covered, divide this distance by 10 to get an average egg diameter. Scott and Crossman (1973) provide egg descriptions for most species. If egg identification is still doubtful, collect a sample of eggs, measure the egg diameter, and preserve the sample in 5% buffered formalin.

Some fish species use spawning strategies which are part-way between broadcast spawners and species which construct spawning nests. These species include Arctic grayling and several sucker species such as longnose and white sucker. No actual nest or redd is prepared but spawning occurs close over the substrate while the fish are vigorously vibrating and the fertilized eggs become somewhat covered by the substrate material stirred up during this vibration. In some cases, such as spawning areas used by a large number of suckers, disturbances of the substrate can be visually observed but it is not possible to enumerate the number of spawning acts or the number of fish involved. For species such as Arctic grayling, these disturbances are indistinct. Spawning surveys for these species are conducted using egg surveys, as for broadcast spawners.

Still other species, such as northern pike and yellow perch, attach their incubating eggs to submerged vegetation (aquatic macrophytes or flooded terrestrial vegetation). Spawning surveys for these species are conducted by searching for eggs in areas of submerged vegetation. A kick sampling net or other small mesh net is swept through the vegetation and the net contents are examined for eggs.

Redd Surveys

Most trout species (including brook, brown, bull, cutthroat and rainbow trout) construct excavations in the substrate into which the fertilized eggs are deposited. A similar excavation immediately upstream of the depression is dug and the materials from this excavation are used to cover the incubating eggs. These excavations or spawning "nests" are termed ***redds*** and are typically constructed in flowing water, although areas of ground-water upwellings in lakes may also be used. As the algae and silt covered rocks are turned over during redd construction, the redds can usually be readily observed due to their "clean" nature and distinctive shape (i.e. distinct depression upstream of a mound). Redd surveys are conducted by one or more observers walking or floating through a study area, enumerating the redds observed, and recording the locations of the redds on a 1:50,00 map of the study area. The study area (section of stream or portion of lake) examined should also be recorded on the map. Not all excavations are redds which contain incubating eggs and it may sometimes be difficult to determine if a disturbance of the streambed is truly a redd. Therefore, redds should be enumerated and classified into the following categories: 1) Class A redd - large or distinct, well formed or spawning fish present; 2) Class B redd - less distinct, most likely an active redd; 3) Class C redd - small or indistinct, possible redd but not definite.

If more than one trout species may be spawning in the study area, enumeration of the redds by species may be difficult. If this is the case, species identification for each redd is best facilitated by conducting the redd survey during the active spawning period so that it is likely that the fish will be present at the redds to aid in identification. Knowing the species and size of the fish in the study area will also help, as some species build larger redds than others. If only one species is expected to be spawning in the study area, the redd survey is usually conducted towards the end of the spawning season when the maximum number of redds will be present.

Repeated redd surveys in the same study area can be used to define the spawning season if required. Surveys are conducted at regular intervals from the start of the spawning season and the number and location of redds on each successive survey is used to determine the length and peak of spawning activity.

3.43 Species Code

Standard abbreviation of fish species names is based on the following rules (MacKay et al. 1990):

a) use a four letter abbreviation
b) for a one word name - use the first four letters
    e.g., GOLD for goldeye
c) two word names - use the first letter in each word plus the next consonant in each word
    e.g., ARGR for Arctic grayling,
    LKWH for lake whitefish, and,
    WHSC for white sucker
    (exception - due to duplication, use BRTR for brook trout and BNTR for brown trout)

d) three word names - use the first letter in the first two words and the first letter and next consonant in the last word

e.g., NRDC for northern redbelly dace

The species codes for all Alberta species are presented on the back of the Fish Sample Record Form.

3.44 Species Composition

A term that refers to the species found in the sampling area.

3.45 Species Distribution

Where the various species in an ecosystem are found at any given time. Species distribution varies with season and life history stage.

3.46 Stage (Life History Stage)

Stage refers to the life history stage (or life stage) of the individual fish. Three stage categories are used to describe free swimming fish: ***fry, juvenile or adult***. The incubating egg is also a life stage and is referred to as the embryo stage.

Fry are also called young-of-the-year (YOY) and are fish from their hatching date until the first anniversary of their hatching date. Juvenile fish are fish from one year old until reaching sexual maturity. Adult fish are fish which are sexually mature.

Definitive life history stage is determined for an individual by internal examination of the gonads. Fry and juvenile fish would have undeveloped gonads and would be classified as immature with respect to state-of-maturity. Fry can usually be separated from juvenile fish by their small size (i.e. smallest fish in the population) and, for some species, by secondary characteristics such as parr marks. Adult fish are sexually mature fish which have spawned in the past or will spawn in the upcoming spawning season. Their state-of-maturity can be one of several categories, from maturing to spent.

Determination of stage from external examination is not always possible. Identification of fry is based on their small size. However, it is not always possible to tell large juvenile fish from small adult fish, in which case an ***unknown*** category is provided in addition to the three main categories. Evidence of sexual maturity, such as secondary sexual characteristics or extrusion of milt or roe during the spawning season can be used to identify adult fish.

3.47 Standard Error and Standard Deviation

Standard error (SE) and standard deviation (SD) both express the variability of results around the mean. However, standard error takes the sample size into consideration when calculated. By including sample size, SE gives an indication of how well we've measured the entire population. This is particularly true if you have very different sample sizes for the groups you are comparing; the larger the sample size, the more confidence you have that the data represents the population.

Standard error is calculated as: $SE=SD \div \sqrt{n}$; where n=sample size. Microsoft Excel will calculate SD automatically. In order to calculate SE the formula in Excel would be " =StDev(cells with data)/(sample size)^0.5". The "^.05" denotes square root (by asking excel to calculate to the power of 0.5).

Standard error is now considered to be the appropriate measure to use in any technical presentation of data and should be used in any figures or tables of fish population statistics.

3.48 Stomach Content/Gut Analysis

Stomach content analysis is used to determine the diet and food preferences of fish. The stomach is removed from the sacrificed individual and opened to allow examination of its contents. Record stomach fullness as the percentage of fullness, from 0 to 100%. Record the contents of the stomach as percentage of the material in the stomach, not as percentage of the total stomach volume (e.g. a stomach that was half full, with all the contents being mayflies would be recorded as follows: 50% full, 100% mayfly).

For invertebrates in the stomach contents, record the contents to the lowest taxonomic level possible. Family level is usually required, but Genus should be recorded if known. Unidentifiable, overdigested invertebrates should be recorded as IR (invertebrate remains) and unidentifiable fish remains should be recorded as FR (fish remains).

3.49 Study Site/Sampling Location

A study site or sampling location is the portion of a study area at which sampling is conducted. The site may be a ***point location*** (such as a gill net or set line location) a ***transect*** (cross section of a stream channel or lake) or a ***section*** (such as a section of stream electrofished or an area of a lake which is seined). In any event, the location of the sampling site must be recorded in the field notes. For large studies or studies with multiple sampling locations on the same waterbody, you may wish to number each sampling site. For a single waterbody, sample site may be numbered sequentially (i.e. #1, #2, etc.). For multiple waterbodies, you may wish to combine the number with an abbreviation for the waterbody (e.g. BR1 = Bow River Site #1). You may also wish to identify the type of sampling conducted (e.g. GN1 = gill net set #1). All study site abbreviations must be clearly identified in the field notes. At a minimum, all study sites should be recorded on a 1:50,000 scale topographical map. Other maps or air photos may also be used if they provide greater detail than the 1:50,000 map. See section 3.17 for additional methods of recording location.

Study areas on flowing watercourses are often divided into homogeneous sections called reaches. A ***reach*** is a relatively homogenous section of stream having a uniform set of characteristics and habitat types. A reach is relatively uniform with respect to channel morphology, flow volume, gradient and habitat types and is separated from other reaches by changes in these characteristics. Conventionally, reach numbers are assigned in an upstream ascending order starting from the mouth of the stream. Typically, reach lengths are too long to sample in their entirety, in which case representative study sections will be selected in each reach for determining species distribution and abundances.

3.50 Temperature Criteria

Water temperature is a very important habitat component. Different fish species have different temperature requirements and have different tolerances to high water temperatures. Temperature regime in lakes and rivers can affect the presence, distribution and abundance of fish species (see Sections 3.7 and 3.9). Temperature criteria provide maximum temperature levels that are tolerable by various life stages and have been developed for selected game fish species. Golder has prepared a document which list the criteria for selected Alberta species (Taylor and Barton 1992).

3.51 Underwater Video

Underwater video equipment includes a remote control underwater camera, light and above surface monitor and video recorder. Underwater video is used to determine fish presence, general abundance and activity. It is not generally useful for recording fish numbers. It is a sampling technique that is effective in both the open water season and for winter sampling under the ice.

3.52 Water Quality

Water quality is a basic aspect of fisheries habitat and can influence fish survival, distribution, abundance and reproductive success. Basic water quality parameters that are measured for fisheries studies include; temperature, dissolved oxygen, pH, conductivity, visibility (secchi depth), turbidity, total suspended solids (TSS) and total dissolved solids (TDS).

3.53 Weight

Weight refers to the total body weight (wet weight) of fish. It is measured for live fish before they are released or for sacrificed fish immediately after they have been killed. Along with length, weight is one of the most basic parameters measured evaluate the key attributes of fish populations.

Weight should be measured **in grams (g)** using a properly calibrated dial scale or electronic scale, depending on fish size. Golder uses dial scales fitted with fork length troughs for measurements of intermediate and large fish. Two types of dial scale are used; small scales which are rated for 0-4 kg in weight are used for most fish species, large scales rated for 0-25 kg are used for large fish species. For forage fish species and fry life stages of large fish species, more sensitive digital electronic scales are used.

3.54 Weight-at-Age

Weight-at-age analysis is used to determine the average weight of fish in each age class in the population. This analysis can only be conducted for individuals for which age is known. For each age class (i.e. 1 year old fish, 2 year old fish, etc.) calculate the range of weights, mean weight and the standard deviation of the mean. Plot this data graphically with age as the X-axis, showing the range, mean and standard deviation (error bars). Weight -at-age is usually plotted on the same graph as length-at-age data.

4 REFERENCES AND SUGGESTED READING

Anderson, R.O. and S.J. Gutreuter. 1983. Length, Weight and Associated Structural Indices. In: Fisheries Techniques. L.A. Nielsen and D. Johnson (eds.). American Fisheries Society, Bethesda, MD. Pp. 283-300.

Armour, C.L., K.P. Burnham, and W.S. Platts. 1983. Field methods and statistical analysis for monitoring small salmonid streams. U.S. Dept. Interior., Fish Wildl. Serv. FWS/OBS-83/33. 200 pp.

Carlander, K.D. 1969. Handbook of Freshwater Fishes of the United States and Canada. 3rd Ed. Iowa State University Press, Ames, I.A.

Hayes, M.L. 1983. Active Capture Techniques. In: Fisheries Techniques. L.A. Nielsen and D.L. Johnson (eds.). American Fisheries Society, Bethesda, M.D. pp. 123-146.

Jearld, A. 1983. Age determination. In: Fisheries Techniques. L.A. Nielsen and D. Johnson (eds.). American Fisheries Society, Bethesda, MD. Pp. 301-324.

MacKay, W.C., Ash, G.R., and H.J. Norris (eds.). 1990. Fish Ageing Methods for Alberta. R.L.&L. Environmental Services Ltd. in assoc. with Alberta Fish and Wildlife Div. and Univ. of Alberta, Edmonton. 113 p.

Nelson, J.S., and M.J. Paetz. The fishes of Alberta (2 ed.). The Univ. of Alberta Press.

Nielson, L.A., and D.L. Johnson. 1983. Fisheries techniques. American Fisheries Society, Bethesda, Mar yland.

Otis, D.L., K.P. Burnham, G.C. White, and D.R. Anderson. 1978. Statistical inference from capture data on closed populations. Wildl. Monogr. 62. 135 pp.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Dept. of Env., Fish. and Marine Serv., Bulletin 191, Ottawa.

Schreck, C.B., and P.B. Moyle. 1990. Methods for fish biology. American Fisheries Society. Bethesda, Maryland.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Bulletin #184, Fisheries Research Board of Canada, Fisheries and Oceans, Ottawa, Ontario. 966 p.

Taylor, B.R., and B.A. Barton. 1992. Temperature and dissolved oxygen criteria for Alberta fishes in flowing water. Prepared for Alberta Fish and Wild life Division, Edmonton, Alberta. 72 pp.

5 DISCUSSION

All basic aspects of each fisheries sampling program should be clear before commencement of field work. The field supervisor and field crew should be appraised by the project manager of all study design details. This will include study objectives, delineation of the study area, sampling techniques, data requirements and budgeting. Conditions at the field site may require alteration of the study design. The field crew should act in coordination with the project manager regarding changes to sampling protocols.

APPENDIX I

MATURITY CODES AND DEFINITIONS

UNKNOWN (UN): This category is used when state-of-maturity cannot be determined. This will most often occur for fish which have only been examined externally, where no examination of the gonads has been conducted. It may also be used following internal examination of the gonads when the observer cannot definitely determine the maturity of the fish. The gonads have been examined but the observer is unsure which maturity category to use, or the conditions of the gonads do not appear to match any of the maturity categories. If this is the case, record a complete description of the gonads and, if possible, collect a sample for microscopic examination.

IMMATURE (IM): This category is for immature fish (fry or juvenile life stages); defined as fish which have never spawned before and will not spawn in the coming spawning season. The gonads will be undeveloped and will be small and largely transparent. They will be string-like organs situated on the dorsal surface of the body cavity (dorsal to other internal organs) and will lie close under the vertebral column. In very young or small fish, determination of sex from examination of the immature gonads may be difficult or impossible.

Male: The testes will typically be smooth in texture and yellow, pink or white in colour. In suckers and percids, immature male testes can be identified by the position of the testicular artery. The artery is usually totally or partially imbedded in the organ.

Female: The ovaries will typically have a granular texture and will be yellow or pink in colour. In suckers and percids, immature female ovaries can be identified by the position of the ovarian artery. The artery is usually completely outside the organ, resting on top of the surface tissue and attached with connective tissue.

MATURING (MA): A maturing fish is a fish which has not spawned before but will spawn in the coming spawning season. This category refers to a fish whose gonads are developing for the first time. Fish in the maturing category are, for the first time, considered adult fish as they are hormonally similar to sexually mature individuals. Since the gonads are developing for the first time, development may not be complete at the time the fish is examined. The gonads may be developed (enlarged and showing sperm or egg development) primarily at the anterior end. The posterior end of the gonad may still be undeveloped and appear thinner (similar to an immature gonad). This category can be difficult to interpret in the field, being difficult to tell from the *Green* category, and examination of the gonads by microscope may be required. In general, the gonads of a maturing fish will be smaller than those for a *Green* fish.

Male: In the field, maturing testes will be smaller and paler than those of fully developed males but considerably larger than immature testes. If unsure, take a sample for histological analysis and designate the fish as *Green* (GN).

Female: In the field, maturing ovaries will be smaller and paler than those of fully developed females but considerably larger than immature ovaries. If unsure, take a sample for histological analysis and designate the fish as *Green* (GN).

SEASONAL DEVELOPMENT (SD): Fish in this category are sexually mature adults which have spawned in one or more previous spawning seasons and will spawn in the coming spawning season. The gonads are undergoing their seasonal development following the last spawning season. This is the longest of the sexually mature stages as it extends from just after the post-spawning period until the next pre-spawning period, as the fish utilizes its resources to produce new gametes. For spring spawning fish (e.g. walleye, northern pike, longnose sucker, rainbow trout, etc.), this category would last from late May to early April of the next year. For fall spawning fish (e.g. lake whitefish, mountain whitefish, bull trout, brook trout, etc.) this category would last from the end of the fall spawning season one year (September to November) through to the fall of the next year. However, for most fish, gonadal development occurs primarily during the growing season with only limited gonadal development during the winter months.

Male: The testes will vary greatly in size and colour within this category depending on the time of year the fish is examined. Early in development (i.e. after the post-spawning period), the testes will be small and yellow to light orange in colour. By early fall (i.e. after the primary gonad development period in the summer), they will have grown to nearly mature size and be white in colour. At this point, the testes will be large and distinct. Note: Suckers have a black coloured testicular membrane which may mask the white colour of the testes.

Female: The ovaries will vary greatly in size and colour within this category depending on the time of year they are sampled. Early in development (i.e. after the post-spawning period), the ovaries will be small and yellow to light orange in colour. Developing oocytes will be small and dark orange in colour and will give the ovary a granular appearance. By early fall (i.e. after the primary gonad development period in the summer), the ovaries will have grown considerably to nearly mature size and be bright yellow to orange in colour. The individual eggs will be readily apparent.

PRE-SPAWNING (PR): Fish in this category are sexually mature adults which have spawned in one or more previous spawning seasons and will spawn in the coming spawning season. The *Pre-spawning* category follows right after the *Seasonal Development* category, with respect to both time and stage of gonadal development, and occurs when the gonads have completed their seasonal development prior to the spawning season. This is a short term condition which extends from time the gonads are fully developed until the start of spawning activity.

Male: Externally the abdomen will be slightly distended. Semen can sometimes be extruded with pressure to the abdomen. If this is the case, small amounts of loose semen will be extruded followed by more viscous semen if pressure is re-applied. Internally, the testes will be large and white and will fill much of the body cavity. Pre-spawning condition can also be inferred by the capture location of the male. Males will usually only enter spawning condition once they are on the spawning grounds and around mature females. Thus a male caught away from the spawning grounds as the spawning season approaches is most likely still in pre-spawning condition, even if some sexual products can be extruded. Note: Semen can be extruded from sexually mature males as early as February in spring spawning species.

Female: Externally the abdomen will be noticeably distended. Sometimes a few eggs can be extruded with strong pressure to the abdomen. Care must be taken when applying pressure as the eggs are difficult to extrude and injury to the female can occur. The abdomen will feel tight and hard. Internally, the ovaries will be large and bright yellow to bright orange in colour. The size can be up to 25% of the total body weight and the gonads will fill much of the body cavity. Individual eggs will be large, round and obvious, some eggs will be translucent. Pre-spawning condition can also be inferred by capture location. Females will usually only enter spawning condition once they are on the spawning grounds and around mature males. Thus a female caught away from the spawning grounds as the spawning season approaches is most likely still in pre-spawning condition, even if some sexual products can be extruded.

RIPE (RP): Fish in this category are sexually mature adults. *Ripe* is the term for the spawning condition. The *Ripe* category follows right after the *Pre-spawning* category, with respect to both time and stage of gonadal development, and occurs when the gametes (semen and eggs) have become loose in the gonads. This is a short term condition which extends from start to the end of spawning activity. Externally the fish will appear as they do during the *Pre-spawning* stage but extrusion of the gametes will occur in response to slight pressure on the abdomen.

Male: Externally the abdomen will be slightly distended. Semen can be extruded with light pressure to the abdomen. Large amounts of loose semen will be produced if pressure is applied. Internally, the testes will be large and white.

Female: Externally the abdomen will be greatly distended. Eggs immersed in ovarian fluid can be extruded with light pressure to the abdomen. Large amounts of loose eggs will be produced if pressure is applied. Internally, the ovaries will be large and yellow or orange. The eggs will be large and translucent and some will appear to be loose as the ovarian tissue is weak (i.e. the ovarian sac will be transparent and thin). Eggs will be loose inside the sac and they will be immersed in clear ovarian fluid.

SPENT (SP): Fish in this category are sexually mature adults. *Spent* is the term for the post-spawning condition. The *Spent* category follows right after the *Ripe* category, with respect to both time and stage of gonadal development, and occurs following spawning activity when the gametes (semen and eggs) have been largely extruded during spawning. This length of time a fish will spend in this category depends on how long it takes for the fish to begin the next cycle of seasonal gonadal development, at which time the fish will again be classified as *Green*.

Male: Externally, the abdomen will be slightly flaccid, especially ventrally. Some semen can still be extruded with pressure to the abdomen but it will most likely be watery (i.e. not as intense a white colour as in spawning males). Internally, the testes will be reduced in size and gray to creamy-white in colour. Hemorrhaging and distended blood vessels on the surface of the organ are common. Post-spawning males are known to stay on the spawning grounds for some time (up to 2 weeks) so capture location is not always a reliable indication of whether the fish has finished spawning.

Female: Externally, the abdomen will be noticeably flaccid, especially ventrally. The surface of the abdomen may be red or roughened with abrasions and the urogenital opening may be extended or swollen. Some eggs can still be extruded with pressure but will be few in number and they will be associated with watery ovarian fluid. Internally, the ovaries will be greatly reduced in size and dark orange to brown in colour. Hemorrhaging and distended blood vessels on the surface of the organ as well as within it are very common and normal. Some residual eggs (from a few up to 25% of the ovary volume) are common. It is not common for post-spawning females to stay on the spawning grounds, most spawn and leave the area immediately. However, capture location is not always reliable indicator.

REABSORBING (RB): Fish in this category are sexually mature fish which have developed to some extent for the coming spawning season but, instead of completing gonadal development or instead of spawning after completing gonadal development, these fish are reabsorbing materials from the gonads back into the body. This category represents arrested gonadal development or interrupted spawning activity. There are several reasons why a fish may terminate gonadal development or decide not to spawn after completing gonadal development. These include the condition of the fish with respect to nutrition and/or health, aspects of population dynamics or environmental cues such as improper water temperatures, poor water quality conditions or adverse water level conditions. Interrupted gonadal development can occur at any stage of development and prior to entering the reabsorbing category the fish may have been *Maturing*, undergoing *Seasonal Development* or in *Pre-spawning* condition.

Male: This condition is *extremely rare in males* and difficult to observe as reabsorption of the semen by the testes is usually a rapid process. Very rarely will a case be observed of a male actually retaining the entire contents of the testes for re-absorption. Should you suspect this condition the testes should be preserved and stage verified by a qualified biologist.

Female: This condition is primarily observed in females. Reabsorption of the eggs by the ovary is usually a lengthy process which can take up to a full year. Some females may retaining the entire contents of the ovaries for re-absorption. Identification of this stage is not always easy. Externally, the female will still have a distended abdomen if caught within a few months of the spawning season. The abdomen will feel unusually hard as compared to normally developing females. Later in the season, it will be impossible to distinguish a normally developing female from a reabsorbing one without an internal examination. Internally, reabsorbing ovaries go through a series of distinct stages. Early in the reabsorption process, the ovary is dark orange to brown in colour. The eggs are dark and flaccid. Heavy amounts of watery ovarian fluid collect at the posterior of the ovary. This fluid most often is ejected readily if the fish is handled. Later, the ovary becomes smaller and hard. The colour becomes darker and the eggs become atritic. Atritic eggs are easily identified as they are small, hard and white. Ovaries in the later stages of eggs reabsorption have few new oocytes. The remnants of the old eggs collect in the middle of the organ. New oocytes production is restricted to the periphery of the ovary. Should you suspect this condition the ovaries should be preserved and stage verified by a qualified biologist. Occasionally, females have been observed which aborted spawning activity after they had became *Ripe*. Functionally speaking, eggs at this stage are no longer connected to the ovaries and cannot be reabsorbed. Instead they remain in the body cavity. Internal examination of a fish in this condition will show the newly developed gonad as well as residual (brown, desiccated) eggs which could not be reabsorbed in the posterior portion of the body cavity.

RESTING (RS): Fish in this category are sexually mature adults which have spawned in one or more previous spawning seasons but will not spawn in the coming spawning season. These fish are different from *Reabsorbing* fish in that their gonads are either not developing or are developing too slowly to be ready for the upcoming spawning season. This is a common condition for fish which do not spawn every year (alternate year spawners).

Male: This condition is *extremely rare in males*. It can only be used as an alternative to the Green category. A few cases of males in the resting condition have been observed. They are most common in northern latitudes where the growing season is short or in ultra-oligotrophic lakes. Testes will appear flaccid and dirty-white to yellow in colour. They will be larger in size than the testes of immature fish. A good indication is the size of the testicular artery in relation to the organ. In immature fish this artery is very thin whereas in resting males the testicular artery is much larger because of prior testicular development. Should you suspect this condition the testes should be preserved and stage verified by a qualified biologist.

Female: This condition is primarily observed in females but is still relatively infrequent, affecting usually only 0.5 to 1% of the population. This stage can only be used as an alternative to the *Green* category. It is most common in northern latitudes where the growing season is short or in ultra-oligotrophic lakes. The ovaries will appear to have some oocytes but they will be few in number and arrested in their development. The colour of resting ovaries varies greatly with fish species but most often they are a light orange. They will be larger in size than the ovaries of immature fish. A good indication is the size of the ovarian artery in relation to the organ. In immature fish this artery is very thin whereas in resting females the ovarian artery is much larger because of prior egg development. Should you suspect this condition the ovaries should be preserved and stage verified by a qualified biologist.

Appendix V.3 Fish Community Composition at Each Sampling Location

Table V.1 **Fish Species Caught and Observed During Collections of White Sucker from Study Lakes, Moira River System, Fall 1999**

Species Common Name	Scientific Name	Study Lakes				
		Consecon	Round	Moira	Stoco	Bend Bay
Largemouth bass	*Micropterus salmoides*		X	X		X
Smallmouth bass	*Micropterus dolomieui*		X	X	X	X
Rock bass	*Ambloplites rupestris*	X			X	X
Yellow perch	*Perca flavescens*	X	X	X	X	X
Walleye	*Stizostedion vitreum*	X	X	X	X	
Northern pike	*Esox lucius*	X	X	X	X	X
Muskellunge	*Esox masquinongy*		X	X	X	
Pumpkinseed sunfish	*Lepomis gibbosus*	X				
unknown sunfish sp.	*Lepomis sp.*		X	X		
White sucker	*Catostomus commersoni*	X	X	X	X	X
Shorthead redhorse	*Moxostoma macrolepidotum*	X		X	X	X
Common carp	*Cyprinus carpio*	X				
Brown bullhead	*Ameiurus nebulosus*	X				X
Longnose gar	*Lepisosteus osseus*	X			X	

Table V.2 **Fish Species Caught and Observed During Collections of Longnose Dace from River Study Sites, Moira River System, Fall 1999**

Species Common Name	Scientific Name	River Study Sites		
		F-1	F-2	F-3
Rock bass	*Ambloplites rupestris*	X	X	X
Bluegill sunfish	*Lepomis macrochirus*		X	
unknown sunfish sp.	*Lepomis sp.*	X		
Longnose dace	*Rhinichthys cateractae*	X	X	X
Fall fish	*Semotilus corporalis*		X	X
Creek chub	*Semotilus atromaculatus*	X	X	X
Johnny darter	*Etheostoma nigrum*	X	X	X

Appendix V.4 Sentinel Fish Species Data

SENTINEL FISH SPECIES DATA

Sex:
F = female
M = male
U = unknown

Species:
WHSC = white sucker
LNDC = longnose dace

Maturity Stage:
SD = seasonal development
MA = maturing
IM = immature
UN = unknown

Longnose Dace Sites:
F-1 = reference site upstream of Malone
F-2 = reference site at Malone
F-3 = exposure site downstream of Deloro Mine

Date	Fish #	Waterbody	Site	Species	Biomarker #	Fork Length (mm)	Total Length (mm)	Total Weight (g)	Carcass Weight (g)	Sex	Maturity Stage	Age	Liver Weight (g)	Gonad Weight (g)	Fecundity (# eggs)	Egg Diameter (mm)	% of Stomach Filled	Stomach Contents
Oct-99	2	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC002	483	512	1665	1432	F	SD	9	20.3	90.8	72331	1.09	0	
Oct-99	1	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC001	491	523	1630	1321	M	SD	18	11.5	121.4			0	
Oct-99	3	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC003	521	562	2081	1802	F	SD	12	25.6	114.3	77835	1.14	0	
Oct-99	4	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC004	473	504	1446	1192	F	SD	15	20.4	83.1	55400	1.04	0	
Oct-99	5	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC005	364	389	794	660	M	SD	5	8.5	62.4			0	
Oct-99	6	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC006	355	377	691	580	M	SD	5	8	41.6			0	
Oct-99	7	Consecon Lake	CL1	WHSC		280		340		M	IM	2						
Oct-99	8	Consecon Lake	CL1	WHSC		274		255		U	IM	4						
Oct-99	9	Consecon Lake	CL1	WHSC		253		216		U	IM	2						
Oct-99	10	Consecon Lake	CL1	WHSC		198		118		U	IM	2						
Oct-99	11	Consecon Lake	CL1	WHSC		166		60		U	IM	1						
Oct-99	12	Consecon Lake	CL1	WHSC		155		52		U	IM							
Oct-99	13	Stoco Lake	SL1	WHSC	MOE99FSL1WHSC013	367	392	707	575	M	SD	7	10.5	59.1			10	mush
Oct-99	14	Stoco Lake	SL1	WHSC	MOE99FSL1WHSC014	309	332	452	372	M	SD	4	5.2	36			0	
Oct-99	15	Stoco Lake	SL1	WHSC	MOE99FSL1WHSC015	324	346	405	359	M	MA	6	5	5.9			0	
Oct-99	16	Stoco Lake	SL1	WHSC	MOE99FSL1WHSC016	328	351	498	411	M	SD	7	5.7	34.5			0	
Oct-99	17	Stoco Lake	SL1	WHSC	MOE99FSL1WHSC017	258	280	238	199	M	SD	6	2	13.7			10	black mush
Oct-99	18	Stoco Lake	SL1	WHSC		233		169		M	IM	3						
Oct-99	19	Stoco Lake	SL1	WHSC	MOE99FSL1WHSC019	295	317	354	294	M	SD	8	3.4	21.8			0	
Oct-99	20	Stoco Lake	SL1	WHSC	MOE99FSL1WHSC020	392	496	815	670	F	SD	13	12.1	39.3	31074	1.14	0	
Oct-99	21	Stoco Lake	SL1	WHSC		169		60		U	IM	2						
Oct-99	22	Stoco Lake	SL1	WHSC		164		49		U	IM	2						
Oct-99	23	Stoco Lake	SL1	WHSC		282		280		M	IM							
Oct-99	24	Stoco Lake	SL1	WHSC		170		61		U	UN							
Oct-99	25	Stoco Lake	SL1	WHSC		231		169		U	UN							
Oct-99	26	Stoco Lake	SL1	WHSC		212		114		U	UN							
Oct-99	27	Stoco Lake	SL1	WHSC		211		130		U	UN							
Oct-99	28	Stoco Lake	SL1	WHSC		235		159		U	UN							
Oct-99	29	Stoco Lake	SL1	WHSC		186		80		U	UN							
Oct-99	30	Moira River	F-2	LNDC	MOE99FMR2LNDC030	73	78	4.083	3.329	F	RB	2	0.048	0.302	1394	0.65	0	
Oct-99	31	Moira River	F-2	LNDC	MOE99FMR2LNDC031	80	87	5.475	5.04	M	SD	2	0.039	0.072			0	
Oct-99	32	Moira River	F-2	LNDC	MOE99FMR2LNDC032	70	76	3.839	3.263	F	SD	1	0.056	0.269	1257	0.62	0	
Oct-99	33	Moira River	F-2	LNDC	MOE99FMR2LNDC033	85	91	5.793	4.926	F	SD	2	0.062	0.353	1161	0.67	0	
Oct-99	34	Moira River	F-2	LNDC	MOE99FMR2LNDC034	71	76	4.239	3.718	M	SD	2	0.06	0.088			0	
Oct-99	35	Moira River	F-2	LNDC	MOE99FMR2LNDC035	70	74	3.602	2.932	F	SD	1	0.064	0.286	1087	0.63	0	
Oct-99	36	Moira River	F-2	LNDC	MOE99FMR2LNDC036	71	76	3.512	2.956	F	SD	1	0.035	0.189	1055	0.58	0	
Oct-99	37	Moira River	F-2	LNDC	MOE99FMR2LNDC037	71	76	3.667	3.277	M	SD	3	0.029	0.047			0	
Oct-99	38	Moira River	F-2	LNDC	MOE99FMR2LNDC038	71	77	3.854	3.412	M	SD	1	0.039	0.046			0	
Oct-99	39	Moira River	F-2	LNDC	MOE99FMR2LNDC039	66	72	3.509	2.909	M	SD	3	0.072	0.05			0	
Oct-99	40	Moira River	F-2	LNDC		51				U	UN							
Oct-99	41	Moira River	F-2	LNDC		54				U	UN							
Oct-99	42	Moira River	F-2	LNDC		45				U	UN							
Oct-99	43	Moira River	F-2	LNDC		42				U	UN							

Date	Fish #	Waterbody	Site	Species	Biomarker #	Fork Length (mm)	Total Length (mm)	Total Weight (g)	Carcass Weight (g)	Sex	Maturity Stage	Age	Liver Weight (g)	Gonad Weight (g)	Fecundity (# eggs)	Egg Diameter (mm)	% of Stomach Filled	Stomach Contents
Oct-99	44	Moira River	F-2	LNDC		44				U	UN							
Oct-99	45	Moira River	F-2	LNDC		49				U	UN							
Oct-99	46	Moira River	F-2	LNDC		53				U	UN							
Oct-99	47	Moira River	F-2	LNDC		46				U	UN							
Oct-99	48	Moira River	F-2	LNDC		43				U	UN							
Oct-99	49	Moira River	F-2	LNDC		43				U	UN							
Oct-99	50	Moira River	F-2	LNDC		63				U	UN							
Oct-99	51	Moira River	F-2	LNDC		42				U	UN							
Oct-99	52	Moira River	F-2	LNDC		45				U	UN							
Oct-99	53	Moira River	F-2	LNDC		62				U	UN							
Oct-99	54	Moira River	F-2	LNDC		43				U	UN							
Oct-99	55	Moira River	F-2	LNDC		41				U	UN							
Oct-99	56	Moira River	F-2	LNDC		43				U	UN							
Oct-99	57	Moira River	F-2	LNDC		47				U	UN							
Oct-99	58	Moira River	F-2	LNDC		42				U	UN							
Oct-99	59	Moira River	F-2	LNDC		44				U	UN							
Oct-99	60	Moira River	F-1	LNDC		47				U	IM							
Oct-99	61	Moira River	F-1	LNDC		38				U	IM							
Oct-99	62	Moira River	F-1	LNDC		47				U	IM							
Oct-99	63	Moira River	F-1	LNDC		39				U	IM							
Oct-99	64	Moira River	F-1	LNDC		48				U	IM							
Oct-99	65	Moira River	F-1	LNDC		44				U	IM							
Oct-99	66	Moira River	F-1	LNDC		43				U	IM							
Oct-99	67	Moira River	F-1	LNDC		45				U	IM							
Oct-99	68	Moira River	F-1	LNDC	MOE99FMR1LNDC068	79	84	5.672	4.741	F	SD	4	0.096	0.373	1838	0.59	0	
Oct-99	69	Moira River	F-1	LNDC	MOE99FMR1LNDC069	75	80	4.523	3.824	F	SD	1	0.061	0.269	1295	0.62	0	
Oct-99	70	Moira River	F-1	LNDC	MOE99FMR1LNDC070	79	85	5.428	4.398	F	SD	2	0.085	0.471	1733	0.63	25	unidentified
Oct-99	71	Moira River	F-1	LNDC	MOE99FMR1LNDC071	79	85	5.386	4.417	F	SD	2	0.09	0.47	2307	0.58	25	unidentified
Oct-99	72	Moira River	F-1	LNDC	MOE99FMR1LNDC072	67	72	3.316	2.8	F	SD	1	0.035	0.223	1017	0.62	0	
Oct-99	73	Moira River	F-1	LNDC		51		1.431		U	IM							
Oct-99	74	Moira River	F-1	LNDC		49		1.3		U	IM							
Oct-99	75	Moira River	F-1	LNDC	MOE99FMR1LNDC075	66	70	3.305	2.79	F	SD	1	0.048	0.155	724	0.58	0	
Oct-99	76	Moira River	F-1	LNDC	MOE99FMR1LNDC076	63	67	2.61	2.211	F	SD	1	0.028	0.124	562	0.64	0	
Oct-99	77	Moira River	F-1	LNDC	MOE99FMR1LNDC077	63	68	3.065	2.604	F	SD	1	0.033	0.191	1005	0.63	0	
Oct-99	78	Moira River	F-1	LNDC	MOE99FMR1LNDC078	78	82	5.19	4.369	F	SD	2	0.066	0.37	1602	0.62	0	
Oct-99	79	Moira River	F-1	LNDC	MOE99FMR1LNDC079	65	73	3.079	2.58	F	SD	3	0.037	0.221	977	0.68	0	
Oct-99	80	Moira River	F-2	LNDC		47				U	IM							
Oct-99	81	Moira River	F-2	LNDC		44				U	IM							
Oct-99	82	Moira River	F-2	LNDC		43				U	IM							
Oct-99	83	Moira River	F-2	LNDC		45				U	IM							
Oct-99	84	Moira River	F-2	LNDC		39				U	IM							
Oct-99	85	Moira River	F-2	LNDC		49				U	IM							
Oct-99	86	Moira River	F-2	LNDC		44				U	IM							

Date	Fish #	Waterbody	Site	Species	Biomarker #	Fork Length (mm)	Total Length (mm)	Total Weight (g)	Carcass Weight (g)	Sex	Maturity Stage	Age	Liver Weight (g)	Gonad Weight (g)	Fecundity (# eggs)	Egg Diameter (mm)	% of Stomach Filled	Stomach Contents
Oct-99	87	Moira River	F-2	LNDC		43				U	IM							
Oct-99	88	Moira River	F-2	LNDC		47				U	IM							
Oct-99	89	Moira River	F-2	LNDC		38				U	IM							
Oct-99	90	Moira River	F-2	LNDC		45				U	IM							
Oct-99	91	Moira River	F-2	LNDC		46				U	IM							
Oct-99	92	Moira River	F-2	LNDC		44				U	IM							
Oct-99	93	Moira River	F-2	LNDC		48				U	IM							
Oct-99	94	Moira River	F-2	LNDC		47				U	IM							
Oct-99	95	Moira River	F-2	LNDC		44				U	IM							
Oct-99	96	Moira River	F-2	LNDC	MOE99FMR2LNDC096	99	107	10.634	8.95	F	SD	4	0.123	0.8	2582	0.69	0	
Oct-99	97	Moira River	F-2	LNDC	MOE99FMR2LNDC097	104	110	12.227	9.805	F	SD	5	0.261	1.135	3363	0.73	0	
Oct-99	98	Moira River	F-2	LNDC	MOE99FMR2LNDC098	88	94	6.822	5.819	F	SD	3	0.067	0.363	1799	0.6	0	
Oct-99	99	Moira River	F-2	LNDC	MOE99FMR2LNDC099	94	100	7.993	6.674	F	SD	5	0.088	0.536	2016	0.69	0	
Oct-99	100	Moira River	F-2	LNDC	MOE99FMR2LNDC100	87	93	7.848	6.162	F	SD	1	0.129	0.605			100	mush
Oct-99	101	Moira River	F-2	LNDC	MOE99FMR2LNDC101	64	70	2.75	2.301	F	SD	2	0.037	0.135	712	0.58	0	
Oct-99	102	Moira River	F-2	LNDC	MOE99FMR2LNDC102	51	55	1.376	1.152	M	SD	1	0.028	0.008			25	black mush
Oct-99	103	Moira River	F-2	LNDC	MOE99FMR2LNDC103	56	60	1.892	1.66	M	SD	0	0.018	0.022			100	black mush, 1 gastropod
Oct-99	104	Moira River	F-2	LNDC		53		1.6		U	IM							
Oct-99	105	Moira River	F-2	LNDC	MOE99FMR2LNDC105	74	79	4.436	3.976	M	SD	2	0.071	0.072			0	
Oct-99	106	Moira River	F-2	LNDC	MOE99FMR2LNDC106	71	77	3.794	3.323	M	SD	2	0.029	0.059			0	
Oct-99	107	Moira River	F-2	LNDC	MOE99FMR2LNDC107	76	82	4.233	3.571	F	SD	2	0.065	0.267	1085	0.63	0	
Oct-99	108	Moira River	F-2	LNDC	MOE99FMR2LNDC108	59	62	2.244	1.985	M	SD	2	0.017	0.027			30	black mush
Oct-99	109	Moira River	F-2	LNDC	MOE99FMR2LNDC109	73	78	3.875	3.221	F	SD	1	0.061	0.298	1669	0.6	0	
Oct-99	110	Moira River	F-2	LNDC	MOE99FMR2LNDC110	65	70	2.823	2.327	F	SD	1	0.042	0.174	1166	0.63	25	black mush
Oct-99	111	Moira River	F-2	LNDC	MOE99FMR2LNDC111	73	79	3.674	3.088	F	SD	1	0.027	0.206	1140	0.63	0	
Oct-99	112	Moira River	F-2	LNDC	MOE99FMR2LNDC112	70	75	3.184	2.718	F	SD	1	0.037	0.098	531	0.56	25	black mush
Oct-99	113	Moira River	F-2	LNDC	MOE99FMR2LNDC113	72	77	3.668	3.314	M	SD	1	0.034	0.041			0	
Oct-99	114	Moira River	F-2	LNDC	MOE99FMR2LNDC114	53		1.466	1.309	M	SD	0	0.021	0.009			0	
Oct-99	115	Moira River	F-2	LNDC	MOE99FMR2LNDC115	67	71	3.302	2.96	M	SD	2	0.036	0.042			0	
Oct-99	116	Moira River	F-2	LNDC	MOE99FMR2LNDC116	72	77	3.979	3.159	F	SD	1	0.084	0.247	1004	0.62	25	black mush
Oct-99	117	Moira River	F-2	LNDC		72		3.878		U	UN	2						
Oct-99	118	Moira River	F-2	LNDC		81		5.493		U	UN	1						
Oct-99	119	Moira River	F-2	LNDC		91		7.655		U	UN	2						
Oct-99	120	Moira River	F-2	LNDC		79		4.958		U	UN	2						
Oct-99	121	Moira River	F-2	LNDC		86		6.974		U	UN	2						
Oct-99	122	Moira River	F-1	LNDC		50				U	IM							
Oct-99	123	Moira River	F-1	LNDC		46				U	IM							
Oct-99	124	Moira River	F-1	LNDC		42				U	IM							
Oct-99	125	Moira River	F-1	LNDC		49				U	IM							
Oct-99	126	Moira River	F-1	LNDC		43				U	IM							
Oct-99	127	Moira River	F-1	LNDC		51				U	IM							
Oct-99	128	Moira River	F-1	LNDC		42				U	IM							
Oct-99	129	Moira River	F-1	LNDC		44				U	IM							

Date	Fish #	Waterbody	Site	Species	Biomarker #	Fork Length (mm)	Total Length (mm)	Total Weight (g)	Carcass Weight (g)	Sex	Maturity Stage	Age	Liver Weight (g)	Gonad Weight (g)	Fecundity (# eggs)	Egg Diameter (mm)	% of Stomach Filled	Stomach Contents
Oct-99	130	Moira River	F-1	LNDC		52				U	IM							
Oct-99	131	Moira River	F-1	LNDC		41				U	IM							
Oct-99	132	Moira River	F-1	LNDC		42				U	IM							
Oct-99	133	Moira River	F-1	LNDC		47				U	IM							
Oct-99	134	Moira River	F-1	LNDC		52				U	IM							
Oct-99	135	Moira River	F-1	LNDC		47				U	IM							
Oct-99	136	Moira River	F-1	LNDC		44				U	IM							
Oct-99	137	Moira River	F-1	LNDC	MOE99FMR1LNDC137	66	71	3.093	2.5	F	SD	1	0.069	0.197	661	0.72	100	unknown black contents
Oct-99	138	Moira River	F-1	LNDC	MOE99FMR1LNDC138	64	68	2.835	2.491	M	SD	1	0.034	0.041			0	
Oct-99	139	Moira River	F-1	LNDC	MOE99FMR1LNDC139	64	68	2.996	2.483	F	SD	1	0.06	0.209	721	0.65	0	
Oct-99	140	Moira River	F-1	LNDC	MOE99FMR1LNDC140	68	73	3.395	2.782	F	SD	1	0.066	0.188	906	0.64	50	black mush
Oct-99	141	Moira River	F-1	LNDC	MOE99FMR1LNDC141	65	70	3.239	2.837	M	SD	1	0.045	0.063			100	black mush
Oct-99	142	Moira River	F-1	LNDC	MOE99FMR1LNDC142	61	65	2.716	2.19	F	SD	1	0.066	0.143	558	0.61	100	black mush
Oct-99	143	Moira River	F-1	LNDC	MOE99FMR1LNDC143	57	61	2.28	1.914	M	SD	2	0.036	0.032			50	black mush
Oct-99	144	Moira River	F-1	LNDC	MOE99FMR1LNDC144	65	69	2.552	2.204	M	SD	2	0.029	0.039			100	black mush
Oct-99	145	Moira River	F-1	LNDC	MOE99FMR1LNDC145	65	69	3.147	2.582	F	SD	1	0.051	0.129	711	0.51	100	black mush
Oct-99	146	Moira River	F-1	LNDC	MOE99FMR1LNDC146	67	72	3.129	2.73	M	SD	1	0.046	0.045			30	black mush
Oct-99	147	Moira River	F-1	LNDC	MOE99FMR1LNDC147	62	67	2.418	2.018	F	SD	3	0.032	0.153	689	0.65	0	
Oct-99	148	Moira River	F-1	LNDC	MOE99FMR1LNDC148	62	66	2.767	2.444	M	SD	4	0.043	0.045			0	
Oct-99	149	Moira River	F-1	LNDC	MOE99FMR1LNDC149	65	70	3.33	2.828	M	SD	2	0.058	0.051			50	black mush
Oct-99	150	Moira River	F-1	LNDC	MOE99FMR1LNDC150	61	65	2.405	2.01	F	SD	1	0.04	0.163	696	0.57	100	black mush
Oct-99	151	Moira River	F-1	LNDC	MOE99FMR1LNDC151	67	72	3.555	2.982	F	SD	2	0.054	0.219	1005	0.63	30	black mush
Oct-99	152	Moira River	F-1	LNDC	MOE99FMR1LNDC152	66	71	3.045	2.513	F	SD	3	0.058	0.211	766	0.62	50	black mush
Oct-99	153	Moira River	F-1	LNDC	MOE99FMR1LNDC153	64	68	2.931	2.515	F	SD	1	0.058	0.119			0	
Oct-99	154	Moira River	F-1	LNDC	MOE99FMR1LNDC154	63	68	2.807	2.475	M	SD	3	0.044	0.038			50	black mush
Oct-99	155	Moira River	F-1	LNDC	MOE99FMR1LNDC155	67	72	3.457	3.009	M	SD	2	0.057	0.059			30	black mush
Oct-99	156	Moira River	F-1	LNDC	MOE99FMR1LNDC156	75	81	4.785	4.155	M	SD	3	0.07	0.08			0	
Oct-99	157	Moira River	F-1	LNDC	MOE99FMR1LNDC157	67	72	3.511	2.882	F	SD	2	0.063	0.191	1118	0.57	50	black mush
Oct-99	158	Moira River	F-1	LNDC	MOE99FMR1LNDC158	60	65	2.355	1.989	F	SD	1	0.036	0.081	507	0.62	0	
Oct-99	159	Moira River	F-1	LNDC	MOE99FMR1LNDC159	66	70	3.138	2.646	F	SD	1	0.052	0.156			10	black mush
Oct-99	160	Moira River	F-1	LNDC	MOE99FMR1LNDC160	69	75	3.649	2.985	F	SD	2	0.059	0.252	1163	0.6	50	black mush
Oct-99	161	Moira River	F-1	LNDC	MOE99FMR1LNDC161	72	78	4.576	4.064	M	SD	2	0.064	0.063			10	black mush
Oct-99	162	Moira River	F-1	LNDC		98		7.687		U	UN	1						
Oct-99	163	Moira River	F-1	LNDC		82		5.69		U	UN	1						
Oct-99	164	Moira River	F-1	LNDC		77		4.752		U	UN	1						
Oct-99	165	Moira River	F-1	LNDC		75		5.421		U	UN	1						
Oct-99	166	Moira River	F-1	LNDC		75		4.84		U	UN	2						
Oct-99	167	Moira River	F-1	LNDC		71		4.234		U	UN	1						
Oct-99	168	Moira River	F-1	LNDC		75		4.368		U	UN	2						
Oct-99	169	Moira River	F-1	LNDC		72		3.937		U	UN	1						
Oct-99	170	Moira River	F-1	LNDC		70		3.423		U	UN	2						
Oct-99	171	Moira River	F-1	LNDC		68		3.398		U	UN	1						
Oct-99	172	Moira River	F-1	LNDC		45				U	IM							

Date	Fish #	Waterbody	Site	Species	Biomarker #	Fork Length (mm)	Total Length (mm)	Total Weight (g)	Carcass Weight (g)	Sex	Maturity Stage	Age	Liver Weight (g)	Gonad Weight (g)	Fecundity (# eggs)	Egg Diameter (mm)	% of Stomach Filled	Stomach Contents
Oct-99	173	Moira River	F-1	LNDC		48				U	IM							
Oct-99	174	Moira River	F-1	LNDC		43				U	IM							
Oct-99	175	Moira River	F-1	LNDC		46				U	IM							
Oct-99	176	Moira River	F-1	LNDC		51				U	IM							
Oct-99	177	Moira River	F-1	LNDC		43				U	IM							
Oct-99	178	Moira River	F-1	LNDC		48				U	IM							
Oct-99	179	Moira River	F-1	LNDC		46				U	IM							
Oct-99	180	Moira River	F-1	LNDC		49				U	IM							
Oct-99	181	Moira River	F-1	LNDC	MOE99FMR1LNDC181	62	66	2.563	2.278	M	SD	2	0.053	0.032			0	
Oct-99	182	Moira River	F-1	LNDC	MOE99FMR1LNDC182	61	65	2.482	2.025	F	SD	1	0.051	0.158	741	0.57	100	black mush
Oct-99	183	Moira River	F-1	LNDC	MOE99FMR1LNDC183	65	70	3.075	2.736	M	SD	3	0.041	0.041			50	black mush
Oct-99	184	Moira River	F-1	LNDC	MOE99FMR1LNDC184	79	85	5.281	4.633	M	SD	4	0.055	0.095			25	black mush
Oct-99	185	Moira River	F-1	LNDC	MOE99FMR1LNDC185	75	80	4.582	4.113	M	SD	3	0.054	0.054			0	
Oct-99	186	Moira River	F-1	LNDC		84		7.2		F	SD							
Oct-99	187	Moira River	F-1	LNDC		84		6.3		F	SD							
Oct-99	188	Moira River	F-2	LNDC		76				U	UN							
Oct-99	189	Moira River	F-2	LNDC		76				U	UN							
Oct-99	190	Moira River	F-2	LNDC		45				U	IM							
Oct-99	191	Moira River	F-2	LNDC		45				U	IM							
Oct-99	192	Moira River	F-2	LNDC		73				U	UN							
Oct-99	193	Moira River	F-2	LNDC		53				U	IM							
Oct-99	194	Moira River	F-2	LNDC		50				U	IM							
Oct-99	195	Moira River	F-2	LNDC		70				U	UN							
Oct-99	196	Moira River	F-2	LNDC		75				U	IM							
Oct-99	197	Moira River	F-2	LNDC		72				U	UN							
Oct-99	198	Moira River	F-2	LNDC		42				U	IM							
Oct-99	199	Moira River	F-2	LNDC		48				U	IM							
Oct-99	200	Moira River	F-2	LNDC		48				U	IM							
Oct-99	201	Moira River	F-2	LNDC		73				U	UN							
Oct-99	202	Moira River	F-2	LNDC		74				U	UN							
Oct-99	203	Moira River	F-2	LNDC		48				U	IM							
Oct-99	204	Moira River	F-2	LNDC		71				U	UN							
Oct-99	205	Moira River	F-2	LNDC		76				U	UN							
Oct-99	206	Moira River	F-2	LNDC		42				U	IM							
Oct-99	207	Moira River	F-2	LNDC		75				U	UN							
Oct-99	208	Moira River	F-2	LNDC		77				U	UN							
Oct-99	209	Moira River	F-2	LNDC		51				U	IM							
Oct-99	210	Moira River	F-2	LNDC		45				U	IM							
Oct-99	211	Moira River	F-2	LNDC		46				U	IM							
Oct-99	212	Moira River	F-2	LNDC		47				U	IM							
Oct-99	213	Moira River	F-2	LNDC		48				U	IM							
Oct-99	214	Moira River	F-2	LNDC		45				U	IM							
Oct-99	215	Moira River	F-2	LNDC		50				U	IM							

Date	Fish #	Waterbody	Site	Species	Biomarker #	Fork Length (mm)	Total Length (mm)	Total Weight (g)	Carcass Weight (g)	Sex	Maturity Stage	Age	Liver Weight (g)	Gonad Weight (g)	Fecundity (# eggs)	Egg Diameter (mm)	% of Stomach Filled	Stomach Contents
Oct-99	216	Moira River	F-2	LNDC		45				U	IM							
Oct-99	217	Moira River	F-2	LNDC		44				U	IM							
Oct-99	218	Moira River	F-2	LNDC		45				U	IM							
Oct-99	219	Moira River	F-2	LNDC		42				U	IM							
Oct-99	220	Moira River	F-2	LNDC		42				U	IM							
Oct-99	221	Moira River	F-2	LNDC	MOE99FMR2LNDC221	56	61	1.745	1.558	M	SD	1	0.011	0.019			0	
Oct-99	222	Moira River	F-2	LNDC	MOE99FMR2LNDC222	68	73	3.514	2.935	F	SD	1	0.056	0.195	868	0.61	100	black mush
Oct-99	223	Moira River	F-2	LNDC	MOE99FMR2LNDC223	71	76	3.767	3.353	M	SD	3	0.048	0.05			0	
Oct-99	224	Moira River	F-2	LNDC	MOE99FMR2LNDC224	56	60	1.598	1.396	M	SD	2	0.016	0.015			0	
Oct-99	225	Moira River	F-2	LNDC	MOE99FMR2LNDC225	68	73	3.104	2.674	F	SD	1	0.048	0.154	575	0.7	0	
Oct-99	226	Moira River	F-2	LNDC	MOE99FMR2LNDC226	54	58	1.446	1.253	M	SD	0	0.014	0.014			0	
Oct-99	227	Moira River	F-2	LNDC	MOE99FMR2LNDC227	76	81	3.858	3.448	M	SD	2	0.061	0.058				
Oct-99	228	Moira River	F-2	LNDC	MOE99FMR2LNDC228	75	80	4.377	3.716	F	SD	2	0.081	0.311	1399	0.61	0	
Oct-99	229	Moira River	F-2	LNDC	MOE99FMR2LNDC229	73	78	3.57	3.067	M	SD	2	0.039	0.042			25	black mush
Oct-99	230	Moira River	F-2	LNDC	MOE99FMR2LNDC230	79	84	4.986	4.513	M	SD	2	0.06	0.051			0	
Oct-99	231	Moira River	F-2	LNDC		102		11.091		U	UN	2						
Oct-99	232	Moira River	F-2	LNDC		99		9.782		U	UN	3						
Oct-99	233	Moira River	F-2	LNDC		94		9		U	UN	2						
Oct-99	234	Moira River	F-2	LNDC		92		7.882		U	UN	1						
Oct-99	235	Moira River	F-2	LNDC		79		4.982		U	UN	1						
Oct-99	236	Moira River	F-2	LNDC		72		4.341		U	UN							
Oct-99	237	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC237	420	447	1100	920	F	SD	4	15.9	69.6	57069	1.11	20	chyme
Oct-99	238	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC238	410	438	1079	929	F	SD	5	13.8	64.9	50032	1.16	20	chyme
Oct-99	239	Consecon Lake	CL1	WHSC		310		380		M	MA							
Oct-99	240	Consecon Lake	CL1	WHSC		294		361		U	IM							
Oct-99	241	Consecon Lake	CL1	WHSC		270		285		U	IM							
Oct-99	242	Consecon Lake	CL1	WHSC		295		340		U	IM							
Oct-99	243	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC243	395	414	949	795	F	SD	6	13.3	59.8	35681	1.4	5	black mush
Oct-99	244	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC244	494	530	2011	1669	F	SD	15	30.1	139.8	87264	1.15	0	
Oct-99	245	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC245	381	450	925	790	F	SD	6	15.8	44	35210	0.93	0	
Oct-99	246	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC246	350	372	639	521	M	SD	6	6	56.9			10	black mush
Oct-99	247	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC247	435	464	1321	1079	M	SD	6	15	133.3			0	
Oct-99	248	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC248	415	440	1120	942	F	SD	6	15.2	65	48575	1.14	0	
Oct-99	249	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC249	445	473	1351	1135	M	SD	10	13.4	108.4			0	
Oct-99	250	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC250	439	468	1231	1060	F	SD	7	14.8	58.6	39686	1.2	0	
Oct-99	251	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC251	435	468	1281	1065	F	SD	6	18.7	89	57605	1.17	50	black mush
Oct-99	252	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC252	408	435	1020	849	M	SD	5	11.5	86.7			0	
Oct-99	253	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC253	341	365	619	524	F	SD	6	7.3	33.5	23914	1.21	0	
Oct-99	254	Consecon Lake	CL1	WHSC						U	UN							
Oct-99	255	Stoco Lake	SL1	WHSC	MOE99FSL1WHSC255	282	295	270		M	SD	8	2.8	13.9			0	
Oct-99	256	Stoco Lake	SL1	WHSC		278		300		U	IM							
Oct-99	257	Stoco Lake	SL1	WHSC		228		160		U	IM							
Oct-99	258	Stoco Lake	SL1	WHSC		270		280		U	IM							

Date	Fish #	Waterbody	Site	Species	Biomarker #	Fork Length (mm)	Total Length (mm)	Total Weight (g)	Carcass Weight (g)	Sex	Maturity Stage	Age	Liver Weight (g)	Gonad Weight (g)	Fecundity (# eggs)	Egg Diameter (mm)	% of Stomach Filled	Stomach Contents
Oct-99	259	Stoco Lake	SL1	WHSC	MOE99FSL1WHSC259	283	300	320	270	M	SD	2	3.1	19.9			0	
Oct-99	260	Stoco Lake	SL1	WHSC		285		309		U	IM							
Oct-99	261	Stoco Lake	SL1	WHSC		236		190		U	IM							
Oct-99	262	Stoco Lake	SL1	WHSC	MOE99FSL1WHSC262	376	398	820	617	F	SD	10	14.6	45.1	32284	1.16	20	black mush
Oct-99	263	Stoco Lake	SL1	WHSC	MOE99FSL1WHSC263	340	365	630	530	F	SD	5	11.4	38.3	27362	1.25	100	green mush
Oct-99	264	Stoco Lake	SL1	WHSC		291		345		U	IM							
Oct-99	265	Stoco Lake	SL1	WHSC		290		310		U	IM							
Oct-99	266	Stoco Lake	SL1	WHSC		198		115		U	IM							
Oct-99	267	Stoco Lake	SL1	WHSC		210		115		U	IM							
Oct-99	268	Stoco Lake	SL1	WHSC	MOE99FSL1WHSC268	374	399	727	595	M	SD	8	7.9	40.3			10	invert parts
Oct-99	269	Moira Lake	ML1	WHSC	MOE99FML1WHSC269	409	442	831	691	M	SD	12	8.5	64.7			0	
Oct-99	270	Moira Lake	ML1	WHSC	MOE99FML1WHSC270	443	476	1149	950	F	SD	7	17.7	62	41437	1.19	0	
Oct-99	271	Moira Lake	ML1	WHSC		426		1085		F	RS	8						
Oct-99	272	Moira Lake	ML1	WHSC	MOE99FML1WHSC272	340	362	543	449	M	SD	5	5.5	34.5			0	
Oct-99	273	Moira Lake	ML1	WHSC	MOE99FML1WHSC273	377	399	663	550	F	SD	12	8.4	34.5	30947	1.13	0	
Oct-99	274	Moira Lake	ML1	WHSC	MOE99FML1WHSC274	363	385	690	580	F	SD	12	11.3	46.2	30875	1.31	0	
Oct-99	275	Moira Lake	ML1	WHSC	MOE99FML1WHSC275	380	409	820	690	F	SD	9	14	55.5	36126	1.26	10	mollusk
Oct-99	276	Moira Lake	ML1	WHSC	MOE99FML1WHSC276	430	458	1250	1030	F	SD	11	22.5	87.7	43388	1.42	0	
Oct-99	277	Moira Lake	ML1	WHSC	MOE99FML1WHSC277	381	410	860	750	F	SD	11	14.5	46.8	31343	1.22	0	
Oct-99	278	Moira Lake	ML1	WHSC	MOE99FML1WHSC278	283	294	330	300	F	IM	3	5.3	2.2			0	
Oct-99	279	Moira Lake	ML1	WHSC	MOE99FML1WHSC279	276	289	270	240	F	IM	4	3.3	1.1			20	chironomids
Oct-99	280	Moira Lake	ML1	WHSC	MOE99FML1WHSC280	418	447	1090	920	F	SD	7	16.1	70.1	47978	1.24	50	
Oct-99	281	Moira Lake	ML1	WHSC	MOE99FML1WHSC281	406	427	980	820	F	SD	7	15.8	55.6	36635	1.18	0	
Oct-99	282	Moira Lake	ML1	WHSC	MOE99FML1WHSC282	332	355	489	401	M	SD	7	4.9	37.8			0	
Oct-99	283	Moira Lake	ML1	WHSC	MOE99FML1WHSC283	382	405	730	620	F	SD	9	13.3	35.6	25225	1.16	0	
Oct-99	284	Moira Lake	ML1	WHSC	MOE99FML1WHSC284	344	367	539	455	M	SD	7	6.2	30.3			2	chironomids
Oct-99	285	Moira Lake	ML1	WHSC	MOE99FML1WHSC285	398	422	970	785	M	SD	12	13.6	79.6			10	chyme
Oct-99	286	Moira Lake	ML1	WHSC	MOE99FML1WHSC286	418	442	1021	822	F	SD	13	18.7	64.5	34239	1.34	0	
Oct-99	287	Moira Lake	ML1	WHSC	MOE99FML1WHSC287	372	395	690	560	F	SD	13	15.9	51.1	29106	1.29	10	chyme
Oct-99	288	Moira Lake	ML1	WHSC	MOE99FML1WHSC288	351	379	550	470	M	SD	9	4.9	25.5			0	
Oct-99	289	Moira Lake	ML1	WHSC	MOE99FML1WHSC289	357	378	650	530	M	SD	12	8.3	33.9			0	
Oct-99	290	Moira Lake	ML1	WHSC	MOE99FML1WHSC290	360	385	592	499	F	SD	14	9.8	31.4	22174	1.09	0	
Oct-99	291	Moira Lake	ML1	WHSC	MOE99FML1WHSC291	403	428	870	730	F	SD	10	12.9	50	32725	1.24	0	
Oct-99	292	Moira Lake	ML1	WHSC	MOE99FML1WHSC292	353	380	641	535	M	SD	10	5.3	39.3			0	
Oct-99	293	Moira Lake	ML1	WHSC	MOE99FML1WHSC293	370	391	680	570	M	SD	10	7.5	54.4			0	
Oct-99	294	Moira Lake	ML1	WHSC	MOE99FML1WHSC294	349	369	640	530	F	SD	9	11.9	38.2	22591	1.33	20	chyme
Oct-99	295	Moira Lake	ML1	WHSC		282		305		M	IM	6						
Oct-99	296	Moira Lake	ML1	WHSC	MOE99FML1WHSC296	373	391	745	610	M	SD	8	7.4	48.7			0	chyme
Oct-99	297	Moira Lake	ML1	WHSC	MOE99FML1WHSC297	422	452	980	830	F	SD	12	13.3	65.6	47219	1.2	0	
Oct-99	298	Moira Lake	ML1	WHSC	MOE99FML1WHSC298	384	409	780	660	M	SD	11	8.3	56.3			0	chyme
Oct-99	299	Moira Lake	ML1	WHSC	MOE99FML1WHSC299	371	400	752	532	F	SD	13	14.4	42	31707	1.2	5	unidentified
Oct-99	300	Round Lake	RL1	WHSC	MOE99FRL1WHSC300	372	399	715	599	M	SD	10	8	42.3			0	
Oct-99	301	Round Lake	RL1	WHSC	MOE99FRL1WHSC301	319	342	421	359	M	SD	5	4.2	18.2			0	

Date	Fish #	Waterbody	Site	Species	Biomarker #	Fork Length (mm)	Total Length (mm)	Total Weight (g)	Carcass Weight (g)	Sex	Maturity Stage	Age	Liver Weight (g)	Gonad Weight (g)	Fecundity (# eggs)	Egg Diameter (mm)	% of Stomach Filled	Stomach Contents
Oct-99	302	Round Lake	RL1	WHSC	MOE99FRL1WHSC302	321	342	390	335	F	SD	9	6.6	21	14540	1.23		
Oct-99	303	Round Lake	RL1	WHSC		172		67		M	IM	2						
Oct-99	304	Round Lake	RL1	WHSC		215		120		U	UN							
Oct-99	305	Round Lake	RL1	WHSC		200		94		U	UN							
Oct-99	306	Round Lake	RL1	WHSC		216		120		U	UN							
Oct-99	307	Round Lake	RL1	WHSC		225		140		F	IM	3						
Oct-99	308	Round Lake	RL1	WHSC		123		21.1		M	IM	1						
Oct-99	309	Round Lake	RL1	WHSC	MOE99FRL1WHSC309	275	288	255	210	M	SD	9	2.6	14.2			0	
Oct-99	310	Round Lake	RL1	WHSC	MOE99FRL1WHSC310	388	409	895	760	F	SD	9	11.8	45.4	28474	1.19	0	
Oct-99	311	Round Lake	RL1	WHSC	MOE99FRL1WHSC311	323	343	440	360	F	SD	7	5.9	22.7	18706	1.07	0	
Oct-99	312	Round Lake	RL1	WHSC	MOE99FRL1WHSC312	285	304	290	245	M	SD	8	2.8	11			0	
Oct-99	313	Round Lake	RL1	WHSC	MOE99FRL1WHSC313	318	337	390	330	F	SD	10	6.2	16	12784	1.13	0	
Oct-99	314	Round Lake	RL1	WHSC		238		170		F	IM							
Oct-99	315	Round Lake	RL1	WHSC		236		160		U	IM							
Oct-99	316	Round Lake	RL1	WHSC		228		170		U	IM							
Oct-99	317	Round Lake	RL1	WHSC		239		170		U	IM							
Oct-99	318	Round Lake	RL1	WHSC		171		70		U	IM							
Oct-99	319	Round Lake	RL1	WHSC		139		50		U	IM							
Oct-99	320	Round Lake	RL1	WHSC		144		40		U	IM							
Oct-99	321	Round Lake	RL1	WHSC		223		140		U	IM							
Oct-99	322	Round Lake	RL1	WHSC	MOE99FRL1WHSC322	322	341	500	425	F	SD	9	9.7	23.3	12639	1.2	0	
Oct-99	323	Round Lake	RL1	WHSC	MOE99FRL1WHSC323	313	331	380	330	F	SD	8	6.3	15.5	10087	1.18	0	
Oct-99	324	Moira River	MR4	WHSC	MOE99FMR4WHSC324	420	455	1020	830	F	SD	13	20	65.8	45982	1.22	0	
Oct-99	325	Moira River	MR4	WHSC	MOE99FMR4WHSC325	355	373	640	550	M	SD	9	7.2	38.8			0	
Oct-99	326	Moira River	MR4	WHSC	MOE99FMR4WHSC326	386	406	780	670	F	SD	10	16	46.3	27058	1.3	0	
Oct-99	327	Moira River	MR4	WHSC	MOE99FMR4WHSC327	386	409	900	750	F	SD	9	20.3	52.7	29480	1.29	0	
Oct-99	328	Moira River	MR4	WHSC	MOE99FMR4WHSC328	374	401	730	600	M	SD	9	8.9	50.1			0	
Oct-99	329	Moira River	MR4	WHSC		100		11.1		U	IM	0						
Oct-99	330	Moira River	MR4	WHSC	MOE99FMR4WHSC330	356	375	600	510	M	SD	7	6.6	36.4			0	
Oct-99	331	Moira River	MR4	WHSC		245		210		F	IM	5						
Oct-99	332	Moira River	MR4	WHSC	MOE99FMR4WHSC332	335	351	520	450	M	SD	8	5.9	27.7			0	
Oct-99	333	Moira River	MR4	WHSC	MOE99FMR4WHSC333	293	309	330	280	F	SD	7	5.4	16.1	13521	1.16	0	
Oct-99	334	Moira River	MR4	WHSC		228		150		M	IM	4						
Oct-99	335	Moira River	MR4	WHSC		187		80		M	IM	1						
Oct-99	336	Moira Lake	ML1	WHSC	MOE99FML1WHSC336	350		630	540	M	SD	9	9.6	34.1			0	
Oct-99	337	Moira Lake	ML1	WHSC	MOE99FML1WHSC337	406	437	906	739	F	SD	12	17.6	44.5	26935	1.31	0	
Oct-99	338	Moira Lake	ML1	WHSC	MOE99FML1WHSC338	330	350	530	450	F	SD	6	8.1	26.2	21729	1.14	0	
Oct-99	339	Moira Lake	ML1	WHSC	MOE99FML1WHSC339	406	439	1073	895	F	SD	11	17.7	69.5	37213	1.26	0	
Oct-99	340	Moira Lake	ML1	WHSC	MOE99FML1WHSC340	376	400	790	660	M	SD	10	11.1	46.1			0	
Oct-99	341	Moira Lake	ML1	WHSC	MOE99FML1WHSC341	366	394	790	652	M	SD	10	13.4	61.9			0	
Oct-99	342	Moira Lake	ML1	WHSC	MOE99FML1WHSC342	423	450	1030	840	F	SD	12	14.7	72.7	37395	1.35	0	
Oct-99	343	Moira Lake	ML1	WHSC	MOE99FML1WHSC343	377	407	782	648	M	SD	9	9.9	50.5			0	
Oct-99	344	Moira Lake	ML1	WHSC	MOE99FML1WHSC344	348	372	580	490	M	SD	10	7.9	44.6			0	

Date	Fish #	Waterbody	Site	Species	Biomarker #	Fork Length (mm)	Total Length (mm)	Total Weight (g)	Carcass Weight (g)	Sex	Maturity Stage	Age	Liver Weight (g)	Gonad Weight (g)	Fecundity (# eggs)	Egg Diameter (mm)	% of Stomach Filled	Stomach Contents
Oct-99	345	Moira Lake	ML1	WHSC	MOE99FML1WHSC345	365	388	730	595	F	SD	8	13.6	54.2	30001	1.33	0	
Oct-99	346	Moira Lake	ML1	WHSC	MOE99FML1WHSC346	331	358	520	450	M	SD	5	4.2	29.7			0	
Oct-99	347	Moira Lake	ML1	WHSC	MOE99FML1WHSC347	331	355	480	400	M	SD	7	5.1	32.6			0	
Oct-99	348	Moira Lake	ML1	WHSC	MOE99FML1WHSC348	438	450	1100	900	F	SD	11	19.7	77.9	42739	1.36	0	
Oct-99	349	Moira Lake	ML1	WHSC		265		260		F	IM	6						
Oct-99	350	Moira Lake	ML1	WHSC		175		186		M	IM	3						
Oct-99	351	Moira River	MR7	WHSC		415		910		F	SD	12						
Oct-99	352	Moira River	MR7	WHSC		285		300		F	SD	5						
Oct-99	353	Moira River	MR7	WHSC		233		170		F	IM	4						
Oct-99	354	Moira River	MR7	WHSC		380		767		F	SD	7						
Oct-99	355	Moira River	MR7	WHSC		203		115		F	SD	4						
Oct-99	356	Moira River	MR7	WHSC		305		350		F	SD	7						
Oct-99	357	Moira River	MR7	WHSC		182		80		M	SD	1						
Oct-99	358	Moira River	MR7	WHSC		190		80		F	IM	4						
Oct-99	359	Moira River	MR7	WHSC		230		160		U	IM	4						
Oct-99	360	Moira River	MR7	WHSC		211		112		U	IM							
Oct-99	361	Moira River	MR7	WHSC		234		152		M	IM	5						
Oct-99	362	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC362	399	422	865	745	F	SD	6	8.2	43.8	32114	1.11	0	
Oct-99	363	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC363	481	416	1628	1330	F	SD	8	25.7	124	58461	1.31	5	unidentified material
Oct-99	364	Consecon Lake	CL1	WHSC		302		380		M	IM							
Oct-99	365	Consecon Lake	CL1	WHSC		193		135		U	IM							
Oct-99	366	Consecon Lake	CL1	WHSC		215		160		U	IM							
Oct-99	367	Consecon Lake	CL1	WHSC		235		195		U	IM							
Oct-99	368	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC368	477	516	1470	1240	F	SD		23.7	63.4	47293	1.14	0	
Oct-99	369	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC369	480	501	1530	1230	M	SD	14	18.2	141			0	
Oct-99	370	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC370	573	605	2500	2030	F	SD	15	41.1	113.6	60167	1.19	10	chyme
Oct-99	371	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC371	415	440	1090	890	M	SD	8	12.6	84.4			0	
Oct-99	372	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC372	451	482	1270	1060	F	SD	8	13.1	77.8	51791	1.17	0	
Oct-99	373	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC373	471	502	1890	1510	F	SD	10	32.7	157.2	85238	1.28	20	black mush
Oct-99	374	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC374	436	465	1350	1110	F	SD	7	12.4	97.7	58426	1.23	0	
Oct-99	375	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC375	435	463	1370	1160	F	SD	11	18.6	71.7	47800	1.19	0	
Oct-99	376	Consecon Lake	CL1	WHSC		316		430		F	IM							
Oct-99	377	Consecon Lake	CL1	WHSC	MOE99FCL1WHSC377	350	374	650	560	F	SD	6	8.5	28.4	25310	1.06	0	
Oct-99	378	Moira River	MR4	WHSC	MOE99FMR4WHSC378	385	412	769	661	F	SD	12	10.8	43	31169	1.2	0	
Oct-99	379	Moira River	MR4	WHSC	MOE99FMR4WHSC379	392	420	820	710	F	SD	7	14.6	38.1	23955	1.21	0	
Oct-99	380	Moira River	MR4	WHSC	MOE99FMR4WHSC380	392	420	892	761	F	SD	11	19.2	51	31911	1.3	0	
Oct-99	381	Moira River	MR4	WHSC	MOE99FMR4WHSC381	404	433	819	680	F	SD	10	14.7	47.9	30915	1.22	0	
Oct-99	382	Moira River	MR4	WHSC	MOE99FMR4WHSC382	360	382	681	575	M	SD	13	15.7	41.7			0	
Oct-99	383	Moira River	MR4	WHSC	MOE99FMR4WHSC383	315	331	425	360	M	SD	10	7.7	22.8			0	
Oct-99	384	Moira River	MR4	WHSC		214		109		U	IM							
Oct-99	385	Moira River	MR4	WHSC		161		54		U	IM							
Oct-99	386	Moira River	MR4	WHSC		124		26		U	IM							
Oct-99	387	Moira River	MR4	WHSC		129		43		U	IM							

Date	Fish #	Waterbody	Site	Species	Biomarker #	Fork Length (mm)	Total Length (mm)	Total Weight (g)	Carcass Weight (g)	Sex	Maturity Stage	Age	Liver Weight (g)	Gonad Weight (g)	Fecundity (# eggs)	Egg Diameter (mm)	% of Stomach Filled	Stomach Contents
Oct-99	388	Moira River	MR4	WHSC	MOE99FMR4WHSC388	360	385	610	510	M	SD	9	6.2	34.1			0	
Oct-99	389	Moira River	MR4	WHSC	MOE99FMR4WHSC389	345	369	590	510	F	SD	7	8.8	31.3	21001	1.19	0	
Oct-99	390	Moira River	MR4	WHSC	MOE99FMR4WHSC390	374	396	670	580	F	SD	9	12.1	38.6	27311	1.21	0	
Oct-99	391	Moira River	MR4	WHSC	MOE99FMR4WHSC391	400	430	860	730	F	SD	9	12.8	49.2	31210	1.23	0	
Oct-99	392	Moira River	MR4	WHSC	MOE99FMR4WHSC392	380	402	800	680	M	SD	11	9.9	43.1			0	
Oct-99	393	Round Lake	RL1	WHSC	MOE99FRL1WHSC393	352	376	601	505	F	SD	6	8.8	29	19302	1.17	0	
Oct-99	394	Round Lake	RL1	WHSC	MOE99FRL1WHSC394	357	380	619	535	M	SD	12	8.1	27.1			0	
Oct-99	395	Round Lake	RL1	WHSC	MOE99FRL1WHSC395	305	326	369	315	F	SD	5	8.7	16.6	13283	1.13	0	
Oct-99	396	Round Lake	RL1	WHSC		252		190		F	IM							
Oct-99	397	Round Lake	RL1	WHSC		141		50		U	IM							
Oct-99	398	Round Lake	RL1	WHSC		142		55		U	IM							
Oct-99	399	Round Lake	RL1	WHSC		218		125		U	IM							
Oct-99	400	Round Lake	RL1	WHSC		242		175		U	IM							
Oct-99	401	Round Lake	RL1	WHSC		243		165		U	IM							
Oct-99	402	Round Lake	RL1	WHSC		236		162		U	IM							
Oct-99	403	Round Lake	RL1	WHSC		195		62		U	IM							
Oct-99	404	Round Lake	RL1	WHSC		255		190		U	IM							
Oct-99	405	Round Lake	RL1	WHSC	MOE99FRL1WHSC405	365	387	630	540	F	SD	10	3.7	31.2	18062	1.35	0	
Oct-99	406	Round Lake	RL1	WHSC	MOE99FRL1WHSC406	347	369	600	490	F	SD	9	8.9	29.7	18314	1.17	0	
Oct-99	407	Round Lake	RL1	WHSC	MOE99FRL1WHSC407	404	431	880	730	F	SD	11	15.6	57.2	33839	1.28	0	
Oct-99	408	Round Lake	RL1	WHSC	MOE99FRL1WHSC408	338	362	540	440	M	SD	6	4.8	33.4			0	
Oct-99	409	Round Lake	RL1	WHSC		259		160		U	IM							
Oct-99	410	Round Lake	RL1	WHSC		247		140		U	IM							
Oct-99	411	Round Lake	RL1	WHSC		211		110		U	IM							
Oct-99	412	Round Lake	RL1	WHSC		183		80		U	IM							
Oct-99	413	Round Lake	RL1	WHSC		180		80		U	IM							
Oct-99	414	Round Lake	RL1	WHSC		215		130		U	IM							
Oct-99	415	Round Lake	RL1	WHSC		215		130		U	IM							
Oct-99	416	Round Lake	RL1	WHSC		182		60		U	IM							
Oct-99	417	Round Lake	RL1	WHSC		159		50		U	IM							
Oct-99	418	Round Lake	RL1	WHSC		155		50		U	IM							
Oct-99	419	Round Lake	RL1	WHSC		145		40		U	IM							
Oct-99	420	Round Lake	RL1	WHSC		153		60		U	IM							
Oct-99	421	Round Lake	RL1	WHSC		166		80		U	IM							
Oct-99	422	Round Lake	RL1	WHSC	MOE99FRL1WHSC422	265	283	260	210	M	SD	7	2.6	10.9			0	
Oct-99	423	Round Lake	RL1	WHSC	MOE99FRL1WHSC423	298	313	330	280	F	SD	6	6.8	14.9	9851	1.25	0	
Oct-99	424	Round Lake	RL1	WHSC	MOE99FRL1WHSC424	280	297	300	250	F	SD	6	6.7	16.4	9662	1.24	0	
Oct-99	425	Round Lake	RL1	WHSC	MOE99FRL1WHSC425	273	287	250	210	F	SD	8	3.4	10.6	7611	1.07	0	
Oct-99	426	Round Lake	RL1	WHSC		213		140		U	IM							
Oct-99	427	Round Lake	RL1	WHSC	MOE99FRL1WHSC427	244	260	200	170	F	SD	3	2.7	8.1	6920	1.02	0	
Oct-99	428	Round Lake	RL1	WHSC	MOE99FRL1WHSC428	333	362	520	450	F	SD	8	7.6	30.5	17679	1.3	0	
Oct-99	429	Moira River	MR6	WHSC		381		818		F	SD	7						
Oct-99	430	Moira River	MR6	WHSC		313		441		F	SD	4						

Date	Fish #	Waterbody	Site	Species	Biomarker #	Fork Length (mm)	Total Length (mm)	Total Weight (g)	Carcass Weight (g)	Sex	Maturity Stage	Age	Liver Weight (g)	Gonad Weight (g)	Fecundity (# eggs)	Egg Diameter (mm)	% of Stomach Filled	Stomach Contents
Oct-99	431	Moira River	MR6	WHSC		375		719		M	SD	8						
Oct-99	432	Moira River	MR6	WHSC		310		429		M	SD	4						
Oct-99	433	Moira River	MR6	WHSC		239		170		M	IM	3						
Oct-99	434	Moira River	MR6	WHSC		304		390		F	IM	5						
Oct-99	435	Moira River	MR6	WHSC		254		203		F	IM	3						
Oct-99	436	Moira River	MR6	WHSC		232		152		F	IM	4						
Oct-99	437	Moira River	MR6	WHSC		221		149		M	IM	2						
Oct-99	438	Moira River	MR6	WHSC		378		659		U	UN							
Oct-99	439	Moira River	MR6	WHSC		360		621		U	UN							
Oct-99	440	Moira River	MR6	WHSC		403		961		U	UN							
Oct-99	441	Moira River	MR6	WHSC		151		32		U	UN	2						
Oct-99	442	Moira River	MR5	WHSC		301		330		F	IM	5						
Oct-99	443	Moira River	MR5	WHSC		275		280		F	SD	5						
Oct-99	444	Moira River	MR5	WHSC		193		90		F	IM	3						
Oct-99	445	Moira River	MR5	WHSC		164		70		F	IM	1						
Oct-99	446	Moira River	MR5	WHSC		155		45		M	IM	1						
Oct-99	447	Moira River	MR5	WHSC		325		430		F	SD	4						
Oct-99	448	Moira River	MR5	WHSC		248		190		F	IM	4						
Oct-99	449	Moira River	MR5	WHSC		242		190		M	SD	6						
Oct-99	450	Moira River	MR5	WHSC		212		120		F	SD	3						
Oct-99	451	Moira River	MR5	WHSC		118		20		F	IM	2						
Oct-99	452	Moira River	MR5	WHSC		180		75		U	IM							
Oct-99	453	Moira River	MR5	WHSC		162		60		U	IM							
Oct-99	454	Moira River	MR5	WHSC		139		39		U	IM							
Oct-99	455	Moira River	MR5	WHSC		134		40		U	IM							
Oct-99	456	Moira River	MR5	WHSC		132		35		U	IM							
Oct-99	457	Moira River	F-3	LNDC	MOE99FMR3LNDC457	103	111	11.541	9.626	F	SD	3	0.177	1.157	2468	0.83	0	
Oct-99	458	Moira River	F-3	LNDC	MOE99FMR3LNDC458	85	91	6.326	5.233	F	SD	3	0.12	0.651	2054	0.75	0	
Oct-99	459	Moira River	F-3	LNDC	MOE99FMR3LNDC459	70	76	3.591	3.013	F	SD	1	0.041	0.309	1260	0.65	0	
Oct-99	460	Moira River	F-3	LNDC	MOE99FMR3LNDC460	90	95	7.286	6.114	F	SD	2	0.125	0.642	2096	0.65	0	
Oct-99	461	Moira River	F-3	LNDC	MOE99FMR3LNDC461	90	96	6.539	5.452	F	SD	4	0.142	0.643	2088	0.69	0	
Oct-99	462	Moira River	F-3	LNDC	MOE99FMR3LNDC462	64	69	3.021	2.715	M	SD	2	0.024	0.043			0	
Oct-99	463	Moira River	F-3	LNDC	MOE99FMR3LNDC463	67	72	3.182	2.917	M	SD	1	0.039	0.049			0	
Oct-99	464	Moira River	F-3	LNDC	MOE99FMR3LNDC464	68	73	3.155	2.85	M	SD	2	0.019	0.035			50	Black mush
Oct-99	465	Moira River	F-3	LNDC	MOE99FMR3LNDC465	76	82	4.448	3.756	F	SD	2	0.075	0.33	1069	0.7	0	
Oct-99	466	Moira River	F-3	LNDC	MOE99FMR3LNDC466	75	80	4.4	3.999	M	SD	1	0.05	0.073			0	
Oct-99	467	Moira River	F-3	LNDC	MOE99FMR3LNDC467	66	71	2.846	2.623	M	SD	1	0.037	0.045			0	
Oct-99	468	Moira River	F-3	LNDC	MOE99FMR3LNDC468	70	75	3.826	3.505	M	SD	2	0.036	0.063			0	
Oct-99	469	Moira River	F-3	LNDC	MOE99FMR3LNDC469	72	76	3.995	3.617	M	SD	2	0.05	0.069			0	
Oct-99	470	Moira River	F-3	LNDC	MOE99FMR3LNDC470	78	84	4.677	4.256	M	SD	3	0.56	0.73			0	
Oct-99	471	Moira River	F-3	LNDC	MOE99FMR3LNDC471	77	82	4.507	3.779	F	SD	2	0.062	0.315	983	0.69	0	
Oct-99	472	Moira River	F-3	LNDC	MOE99FMR3LNDC472	70	75	3.433	2.975	F	SD	1	0.037	0.197	862	0.63	0	
Oct-99	473	Moira River	F-3	LNDC	MOE99FMR3LNDC473	66	70	3.157	2.812	M	SD	2	0.036	0.049			100	snails

Date	Fish #	Waterbody	Site	Species	Biomarker #	Fork Length (mm)	Total Length (mm)	Total Weight (g)	Carcass Weight (g)	Sex	Maturity Stage	Age	Liver Weight (g)	Gonad Weight (g)	Fecundity (# eggs)	Egg Diameter (mm)	% of Stomach Filled	Stomach Contents
Oct-99	474	Moira River	F-3	LNDC	MOE99FMR3LNDC474	72	76	3.436	2.912	F	SD	1	0.035	0.215	751	0.63	100	black mush
Oct-99	475	Moira River	F-3	LNDC	MOE99FMR3LNDC475	69	75	3.32	2.988	M	SD	3	0.029	0.06			0	
Oct-99	476	Moira River	F-3	LNDC	MOE99FMR3LNDC476	72	78	3.802	3.391	M	SD	4	0.041	0.067			80	black mush
Oct-99	477	Moira River	F-3	LNDC	MOE99F`LNDC477	77	82	4.286	3.858	M	SD	4	0.052	0.061			100	black mush
Oct-99	478	Moira River	F-3	LNDC	MOE99FMR3LNDC478	63	69	2.633	2.399	M	SD	2	0.026	0.034			0	
Oct-99	479	Moira River	F-3	LNDC	MOE99FMR3LNDC479	71	77	3.662	3.326	M	SD	2	0.043	0.08			0	
Oct-99	480	Moira River	F-3	LNDC	MOE99FMR3LNDC480	73	79	4.404	3.692	F	SD	4	0.055	0.355	1049	0.73	0	
Oct-99	481	Moira River	F-3	LNDC	MOE99FMR3LNDC481	75	80	4.497	3.828	F	SD	2	0.081	0.271	1134	0.67	0	
Oct-99	482	Moira River	F-3	LNDC	MOE99FMR3LNDC482	64	70	2.733	2.39	F	SD	2	0.049	0.094	321	0.55	0	
Oct-99	483	Moira River	F-3	LNDC	MOE99FMR3LNDC483	65	71	3.114	2.702	F	SD	1	0.07	0.191	813	0.7	0	
Oct-99	484	Moira River	F-3	LNDC	MOE99FMR3LNDC484	67	72	3.192	2.896	M	SD	1	0.03	0.057			0	
Oct-99	485	Moira River	F-3	LNDC	MOE99FMR3LNDC485	85	92	6.124	5.554	M	SD	5	0.082	0.098			0	
Oct-99	486	Moira River	F-3	LNDC	MOE99FMR3LNDC486	86	92	6.88	5.556	F	SD	3	0.106	0.761	2468	0.74	0	
Oct-99	487	Moira River	F-3	LNDC	MOE99FMR3LNDC487	70	76	3.348	2.936	F	SD	1	0.37	0.194	683	0.69	0	
Oct-99	488	Moira River	F-3	LNDC	MOE99FMR3LNDC488	71	77	3.66	3.322	M	SD	2	0.33	0.062			0	
Oct-99	489	Moira River	F-3	LNDC	MOE99FMR3LNDC489	70	75	3.688	3.101	F	SD	2	0.064	0.291	1074	0.73	0	
Oct-99	490	Moira River	F-3	LNDC	MOE99FMR3LNDC490	83	90	5.779	4.829	F	SD	3	0.077	0.469	1320	0.72	10	black mush
Oct-99	491	Moira River	F-3	LNDC	MOE99FMR3LNDC491	81	88	5.289	4.802	M	SD	3	0.051	0.054			0	
Oct-99	492	Moira River	F-3	LNDC	MOE99FMR3LNDC492	83	90	5.877	5.419	M	SD	4	0.041	0.093			0	
Oct-99	493	Moira River	F-3	LNDC	MOE99FMR3LNDC493	65	70	3.082	2.857	M	SD	1	0.032	0.052			0	
Oct-99	494	Moira River	F-3	LNDC	MOE99FMR3LNDC494	72	78	4.299	3.626	F	SD	2	0.072	0.344	1113	0.78	0	
Oct-99	495	Moira River	F-3	LNDC	MOE99FMR3LNDC495	100	108	10.249	8.567	F	SD	3	0.162	0.684	2443	0.7	30	black mush
Oct-99	496	Moira River	F-3	LNDC	MOE99FMR3LNDC496	90	97	7.703	6.385	F	SD	3	0.115	0.548	1536	0.69	100	snails
Oct-99	497	Moira River	F-3	LNDC		95		9.489		U	UN	3						
Oct-99	498	Moira River	F-3	LNDC		89		7.646		U	UN	2						
Oct-99	499	Moira River	F-3	LNDC		48		1.142		U	IM	0						
Oct-99	500	Moira River	F-3	LNDC		46		1.081		U	IM	0						
Oct-99	501	Moira River	F-3	LNDC		40		0.777		U	IM	0						
Oct-99	502	Moira River	F-3	LNDC		41		0.854		U	IM	0						
Oct-99	503	Moira River	F-3	LNDC		42		0.867		U	IM	0						
Oct-99	504	Moira River	F-3	LNDC		44		0.858		U	IM	0						
Oct-99	505	Moira River	F-3	LNDC		45		0.881		U	IM	0						
Oct-99	506	Moira River	F-3	LNDC		40		0.656		U	IM	0						

APPENDIX VI

TOXICOLOGICAL PROFILES OF THE METALS OF CONCERN FOR HUMAN HEALTH

Arsenic

Lowest Observed Adverse Effect Levels (LOAELs) for acute human exposure to arsenic are about 1 mg/kg/day (ATSDR 1993a). The oral RfD for arsenic is 0.3 µg/kg/day. The most likely human health effects of oral exposure to arsenic are gastrointestinal irritation, peripheral neuropathy, vascular lesions, anemia and a group of skin diseases. Acute ingestion of low levels of arsenic trioxide may cause nausea, vomiting and diarrhea; ingestion of higher concentrations (>70 mg) are usually fatal (Ariza *et al.* 1999). The data available on the acute effects of oral exposure to arsenic are mainly from case reports of fatal or near fatal exposures. It is likely that lower acute exposures could also produce characteristic signs of arsenic toxicity. For intermediate-duration exposure most oral LOAELs range from 0.05 to 0.5 mg/kg/day (ATSDR 1993a)

Little information is available on the effects due to dermal contact with inorganic arsenic. The chief effect is local irritation and dermatitis. A dermal NOAEL of 580 mg/L As^{+3} was identified for the guinea pig (ATSDR 1993a).

No studies were located regarding unusual susceptibility of any human population to arsenic. Given that the degree of arsenic toxicity may be influenced by the rate and extent of its methylation in the liver, it is likely that members of the population with a lower than normal methylating capacity will be susceptible to arsenic toxicity.

Arsenic is also considered a carcinogen via the oral route. The U.S. EPA (1998) has derived an oral cancer potency factor of 0.0015 µg/kg/day based on an increased incidence of skin cancer in humans exposed to arsenic via their drinking water.

Cobalt

Oral exposure to cobalt (frequently cobalt chloride) by humans can cause nausea, vomiting, polycythemia and minor cardiovascular effects. An oral RfD of 60 µg/kg/day has been established by the U.S. EPA (1997) based on polycythemia in renally compromised and normal patients.

There are no data that indicate that cobalt causes cancer.

Cadmium

The primary toxicological endpoint following oral exposure to cadmium is proteinuria (i.e., excess protein in the urine). Gastrointestinal absorption is about 5 to 8% (Goyer 1996). Absorption is enhanced by dietary deficiencies of calcium, iron and protein and in women, low serum ferritin levels (Goyer 1996). Gastrointestinal effects have occurred at consumption of drinks containing approximately 16 mg per litre of cadmium (Nordberg 1972). Recovery was rapid with no long-term effects. Common symptoms of cadmium ingestion include nausea, vomiting, salivation, abdominal pain, cramps and diarrhea (ATSDR 1993b). The emetic dose is 0.07 mg/kg (ATSDR 1993b).

Skin contact with cadmium is not known to cause health effects in humans or animals (ATSDR 1993b).

Young children and populations with dietary deficiencies of calcium, iron, protein, and vitamin D have increased cadmium absorption from the gastrointestinal tract, making them potentially more susceptible to cadmium toxicity. Also, populations with kidney damage from causes unrelated to cadmium exposure, including diabetes, are expected to be more susceptible to cadmium-related nephrotoxicity.

Although cadmium is classified as a human carcinogen via inhalation, there are no data to indicate that cadmium can cause cancer following oral or dermal exposures.

Nickel

Oral exposure to nickel and nickel compounds can result in an increased incidence of allergic contact dermatitis, eczema and respiratory effects in humans.

There are no data to indicate that metallic nickel is carcinogenic.

Chromium

Ingestion of chromium (VI) can cause stomach upsets, ulcers, convulsions and kidney and liver damage. Death has also occurred after accidental chromium poisoning. A man died of severe gastrointestinal haemorrhage after ingesting 4.1 mg/kg of chromic acid (ATSDR 1993c). A boy died after ingestion of 7.5-mg/kg potassium dichromate (ATSDR 1993c). A woman who ingested a few grams of potassium dichromate experienced renal effects and regained renal function following dialysis. She also experienced decreased haemoglobin content and hematocrit, increased total white blood cell counts, reticulocyte counts and plasma haemoglobin.

Dermatitis in chromium-sensitive workers has been found to worsen after ingestion of 0.036-mg/kg chromium as potassium dichromate (ATSDR 1993c).

Acute oral exposure to chromium can cause dermal, ocular, immunological, gastrointestinal, haematological, renal, hepatic, neurological and cardiovascular effects. Respiratory, cardiovascular, haematological, hepatic and neurological effects in humans as a result of chromium ingestion have only been identified for extreme cases where death occurred or large amounts were ingested associated with occupational exposure.

Allergic chromium skin reactions readily occur with exposure and are independent of dose in allergic individuals (Goyer 1996). Eczema and dermatitis (ATSDR 1993c) characterize allergic skin reactions. Acute dermal exposure of humans to chromium (VI) compounds causes skin burns. Cases of such skin burns are a result of accidental occupational or therapeutic exposure.

Individuals who are sensitive to chromium may develop asthma as an anaphylactic response to inhaled chromium (ATSDR 1993c). Some individuals have less ability than others to reduce chromium (VI) in the bloodstream and are more likely to be affected by the adverse effects of chromium exposure (ATSDR 1993c). Based upon animal studies and occupational exposure studies, young people may be more susceptible to toxic effects of chromium than adults (ATSDR 1993c).

Lead

The level of lead causing a toxic effect is commonly expressed through blood lead levels. Studies have been conducted to correlate environmental lead levels with blood lead levels and slope factors have been developed to predict the increases in blood lead per unit lead concentration in environmental media (ATSDR 1993d). Slopes range between 0.0007 and 0.0068 µg/dL blood lead increase per mg/kg soil lead (ATSDR 1993d).

Lead is neurotoxic with varying symptoms. Exposure of children to high levels may cause encephalopathy and/or irreversible mental retardation (Goyer 1996). Symptoms of lead encephalopathy begin with lethargy, vomiting, irritability, loss of appetite and dizziness, progressing to ataxia, a reduced level of consciousness, which may progress to coma and death. Encephalopathy can occur at blood lead levels of 100-120 µg/dL in adults and 80-100 µg/dL in children (ATSDR 1993d).

In adults, lead neurotoxicity can result in depression, affective or schizophreniform-like psychosis, irritability, decreased libido, fatigue, anger, tension and interpersonal conflicts. Adults have been found to have overt neurological signs and symptoms at blood lead levels of 40-60 µg/dL (ATSDR 1993d). In children, neurobehavioural impairment has been associated with blood lead levels of 50 – 70 µg/dL (ATSDR 1993d).

At high levels of exposure, lead produces cardiac lesions and cardiac abnormalities (ATSDR 1993d).

Lead interferes with heme biosynthesis and has multiple haematology effects. In humans a LOAEL of 0.02 mg/kg/day was related to decreased δ-aminolevulenic acid dehydratase (ALAD) activity (ATSDR 1993d).

Acute lead-induced kidney damage in humans includes inclusion bodies, mitochondrial changes and damage to the proximal tubules (Fanconi's syndrome) which results in aminoaciduria, glucosuria and hyperphosphaturia. These effects appear to be reversible. Fanconi's syndrome is estimated to occur in approximately 1/3 of children at approximately 150 µg/dL (ATSDR 1993d). Nephropathy occurs in children at blood levels >80 µg/dL (ATSDR 1993d).

Colic, which is characterized by abdominal pain, constipation, cramps, nausea, vomiting, anorexia and weight loss is a symptom of individuals acutely exposed to high levels (40 to 200 µg/dL) of lead (ATSDR 1993d).

Children are at the greatest risk for experiencing lead-induced health effects. This is due to a number of factors: 1) young children (<5 years old) absorb ingested lead more efficiently (50% relative absorption) than adults (15% relative absorption); 2) behaviour such as thumb sucking and pica result in elevated transfer of lead-contaminated dust and dirt; 3) children have an immature detoxification enzyme system resulting in increased retention and body burdens of lead and 4) children have lower thresholds expressed as blood lead concentration for haematological and neurological effects (ATSDR 1993d).

Developing fetuses are at an increased risk due to the inherent susceptibility of the developing nervous systems and exposure arising from transplacental transfer of maternal lead. Toxic effects of lead exposure are exacerbated in individuals with inherited genetic diseases, such at thalassemia, which is characterized by an abnormality in the rate of haemoglobin synthesis. People with neurological dysfunction or kidney disease are unusually susceptible to lead exposure. The neurological system and the kidney are the targets of lead intoxication and as a result persons with neurological dysfunction or kidney disease may become overburdened at much lower threshold concentrations to elicit manifestations of lead intoxication (ATSDR 1993d).

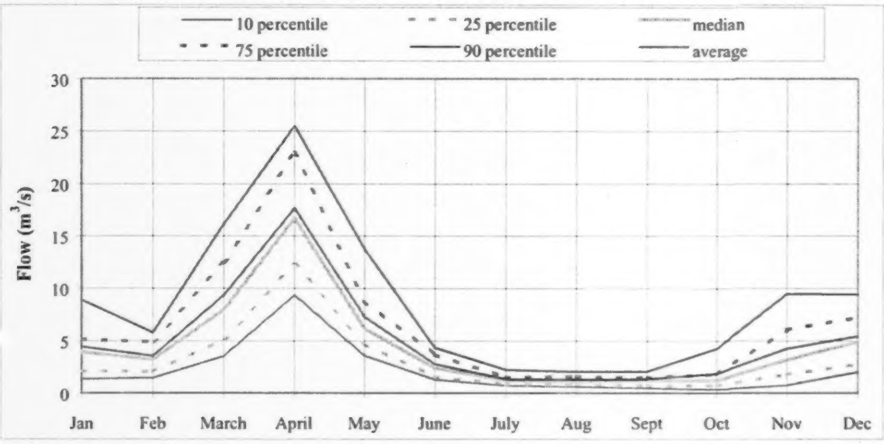
Lead has been classified by the US EPA as a probable human carcinogen, but a quantitative cancer risk estimate was not derived due to the lack of understanding of the toxicological properties of lead. The US EPA also identified that neurobehavioural effects are a more sensitive and toxicologically relevant endpoint than cancer.

APPENDIX VII

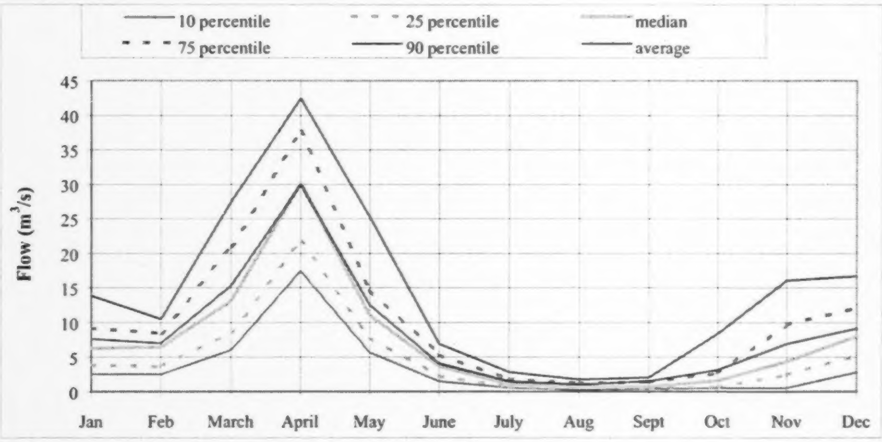
SUPPORTING DATA FOR MODEL AND CALIBRATION RESULTS

Appendix VII.1 Flows in Tributaries of the Moira River

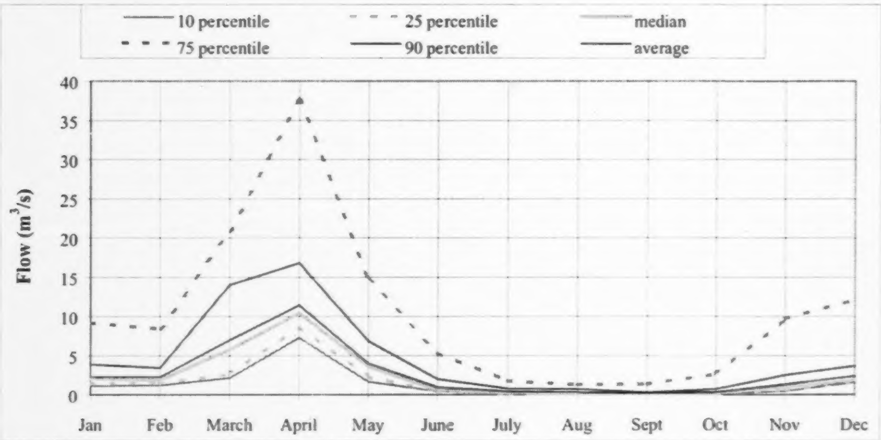
Black River n = 38 to 41



Skootamatta n = 39 to 40



Clare River n = 6 to 9



Appendix VII.2 Results of Model Calibration

Figure VII-1 **Predicted and Observed Arsenic Levels in the Moira River from Deloro to Young's Creek (1990 to 2000)**

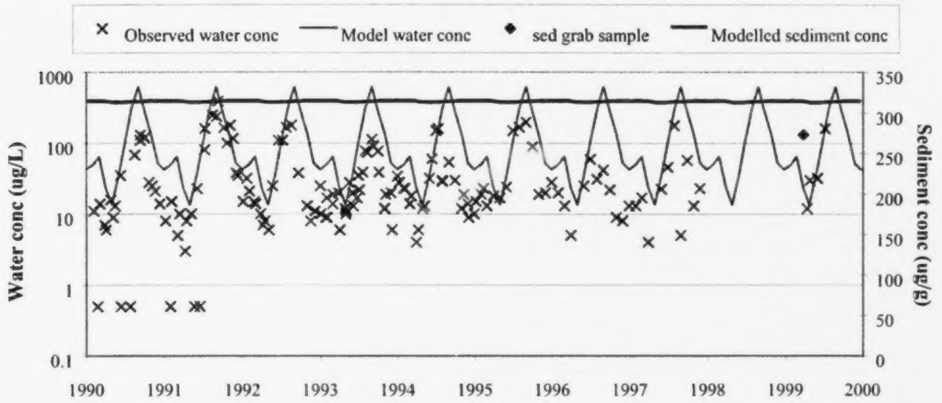


Figure VII-2 **Predicted and Observed Arsenic Levels in the Moira River from Young's Creek to Half Way to Bend Bay (1990 to 2000)**

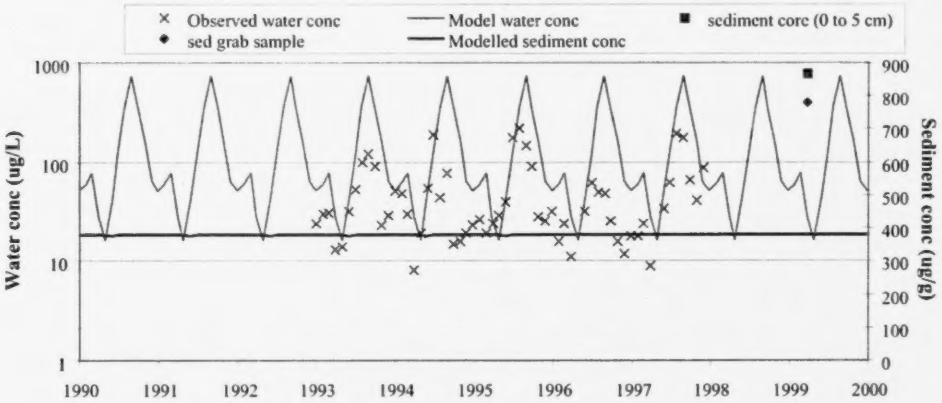


Figure VII-3 Predicted and Observed Arsenic Levels in the Moira River from Half Way to Bend Bay to Bend Bay (1990 to 2000)

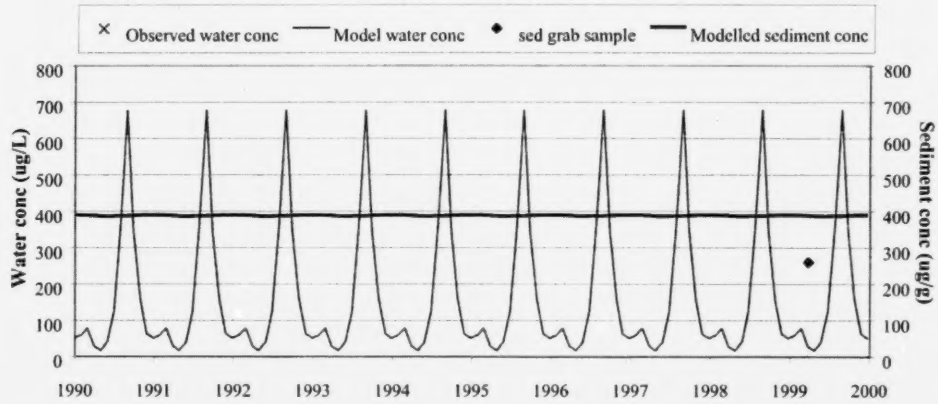


Figure VII-4 Predicted and Observed Arsenic Levels in Bend Bay (1990 to 2000)

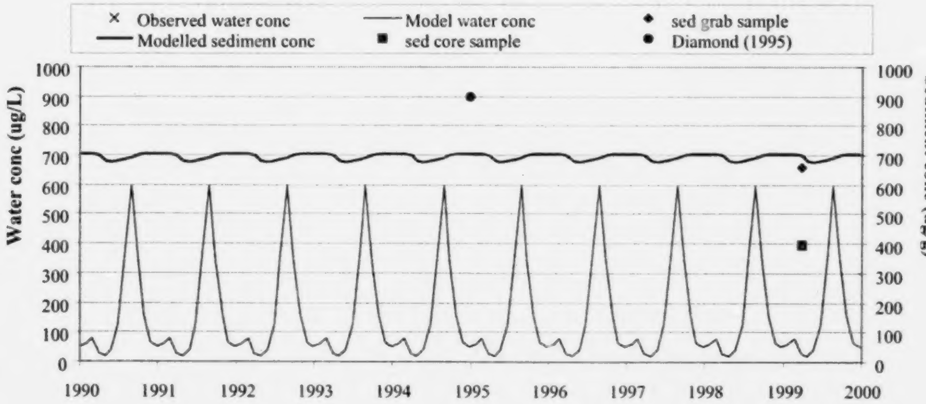


Figure VII-5 Predicted and Observed Arsenic Levels in West Moira Lake (1990 to 2000)

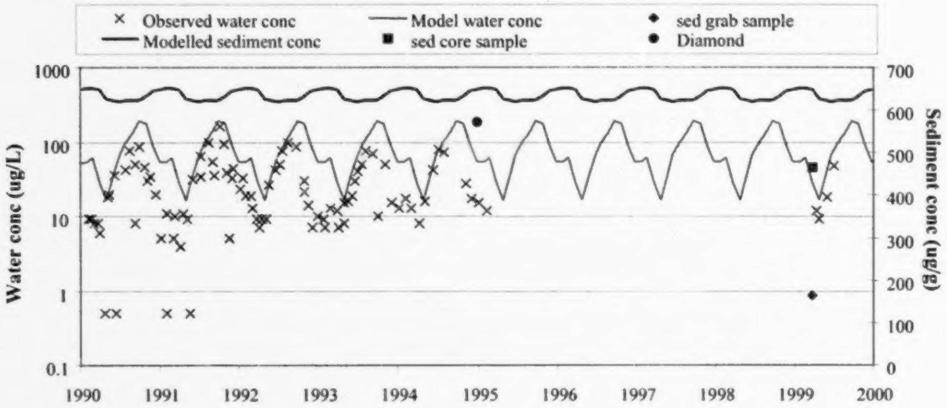


Figure VII-6 Predicted and Observed Arsenic Levels in East Moira Lake (1990 to 2000)

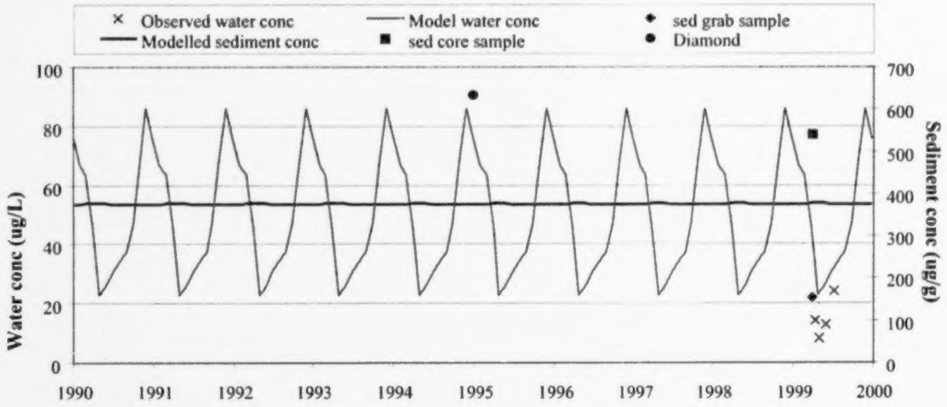


Figure VII-7 Predicted and Observed Arsenic Levels in the Moira River from East Moira Lake to Stoco Lake (1990 to 2000)

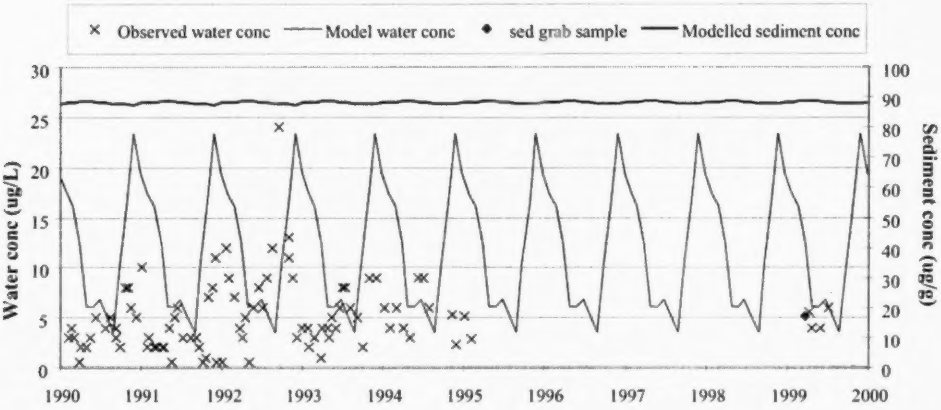


Figure VII-8 Predicted and Observed Arsenic Levels in Stoco Lake (1990 to 2000)

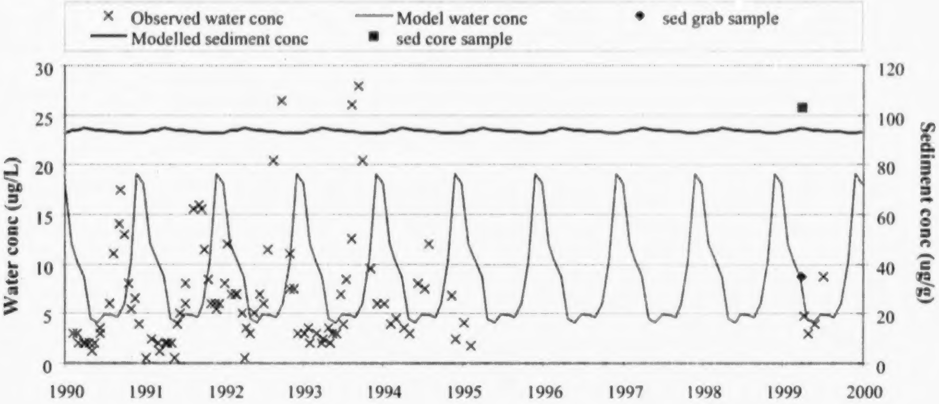


Figure VII-9 **Predicted and Observed Cobalt Levels in the Moira River from Deloro to Young's Creek (1990 to 2000)**

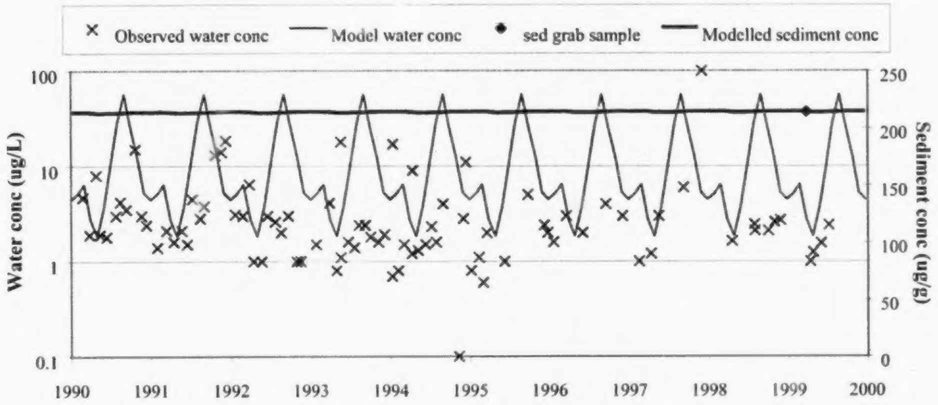


Figure VII-10 **Predicted and Observed Cobalt Levels in the Moira River from Young's Creek to Half Way to Bend Bay (1990 to 2000)**

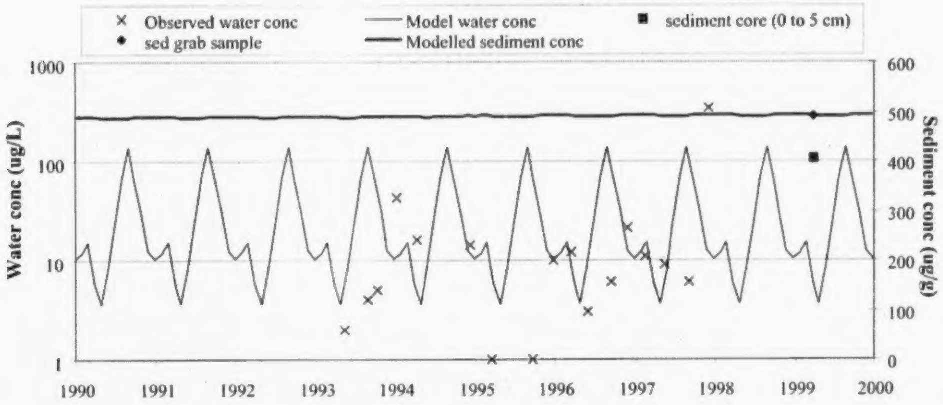


Figure VII-11 **Predicted and Observed Cobalt Levels in the Moira River from Half Way to Bend Bay to Bend Bay (1990 to 2000)**

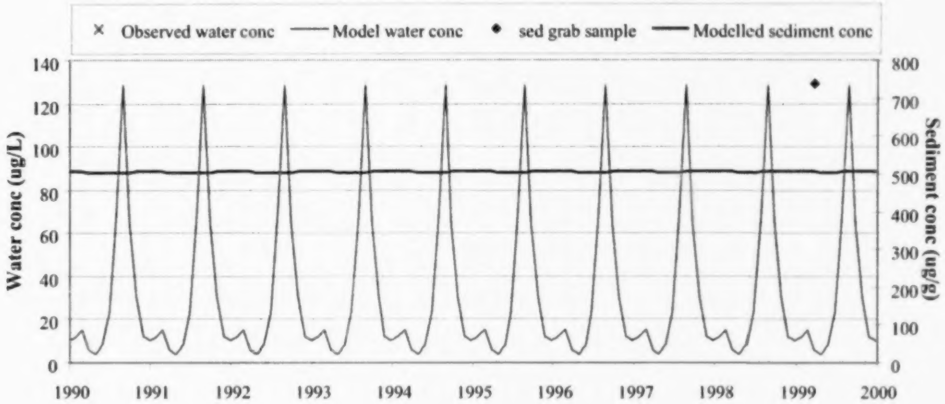


Figure VII-12 **Predicted and Observed Cobalt Levels in Bend Bay (1990 to 2000)**

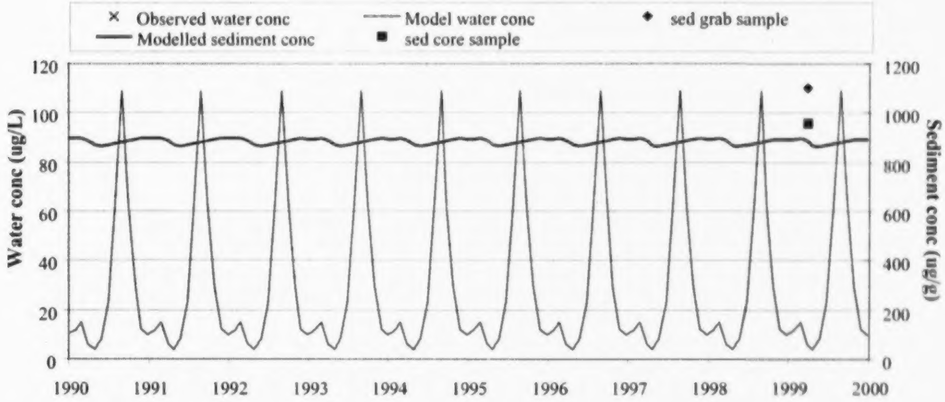


Figure VII-13 Predicted and Observed Cobalt Levels in West Moira Lake (1990 to 2000)

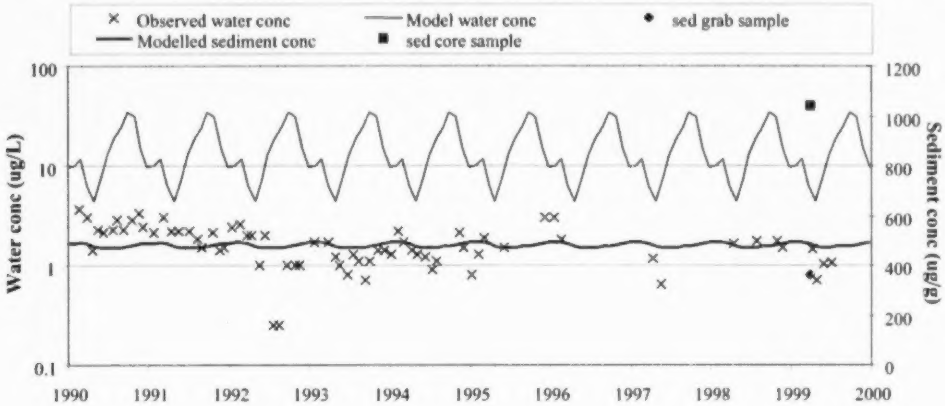


Figure VII-14 Predicted and Observed Cobalt Levels in East Moira Lake (1990 to 2000)

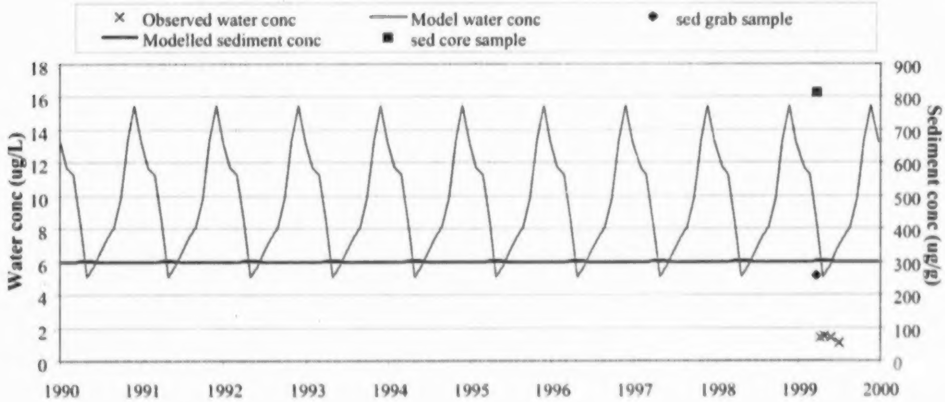


Figure VII-15 Predicted and Observed Cobalt Levels in the Moira River from East Moira Lake to Stoco Lake (1990 to 2000)

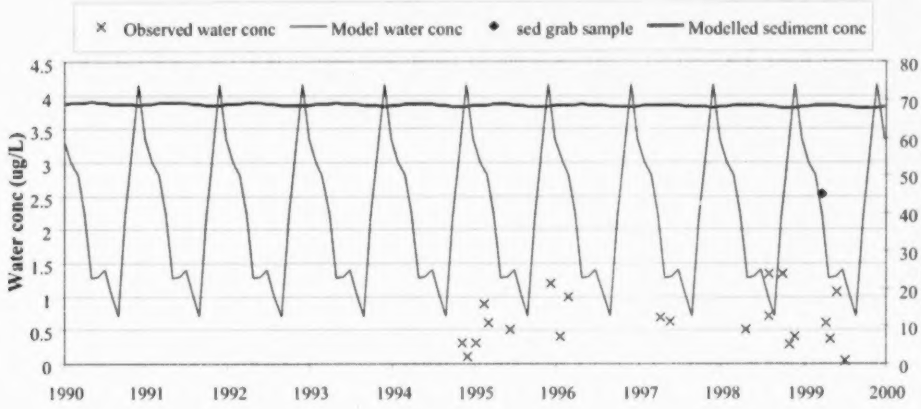


Figure VII-16 Predicted and Observed Cobalt Levels in Stoco Lake (1990 to 2000)

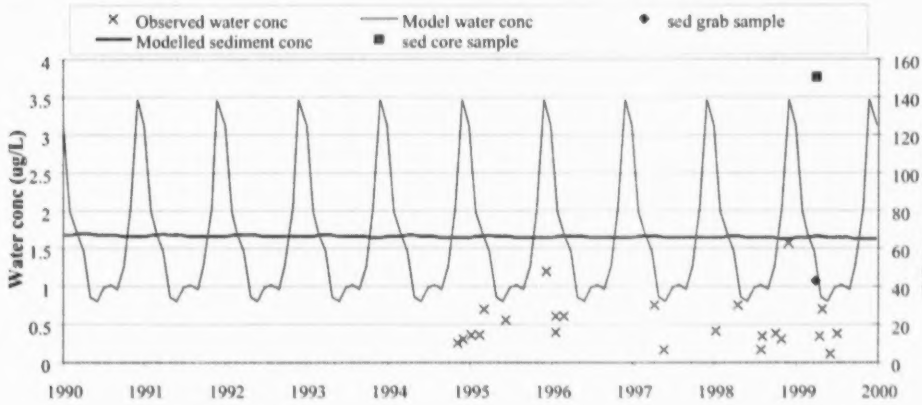


Figure VII-17 Predicted and Observed Nickel Levels in the Moira River from Deloro to Young's Creek (1990 to 2000)

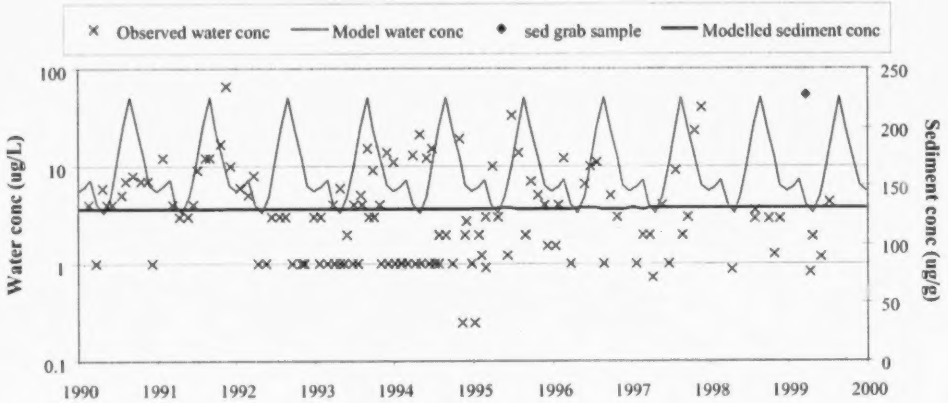


Figure VII-18 Predicted and Observed Nickel Levels in the Moira River from Young's Creek to Half Way to Bend Bay (1990 to 2000)

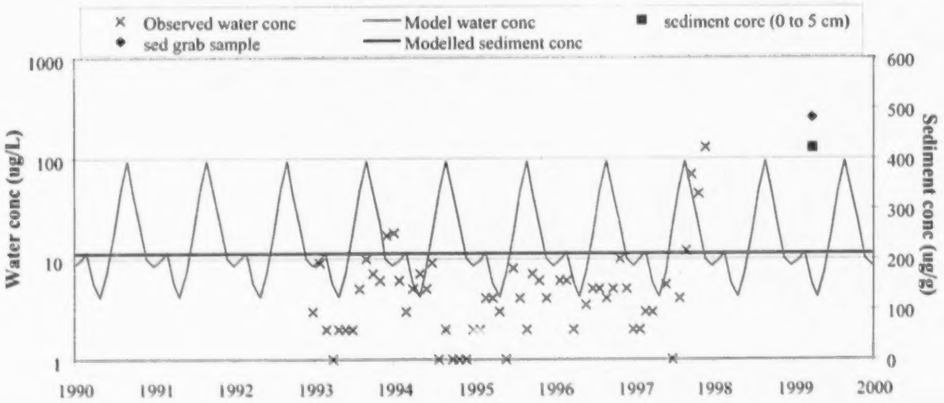


Figure VII-19 Predicted and Observed Nickel Levels in the Moira River from Half Way to Bend Bay to Bend Bay (1990 to 2000)

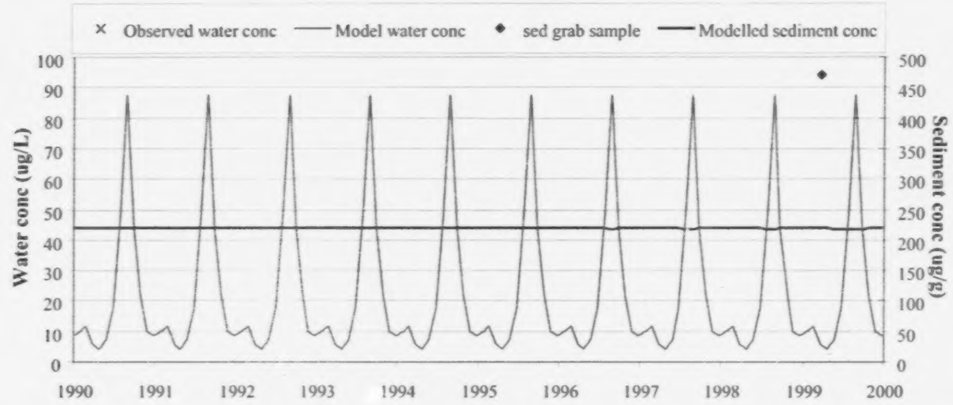


Figure VII-20 Predicted and Observed Nickel Levels in Bend Bay (1990 to 2000)

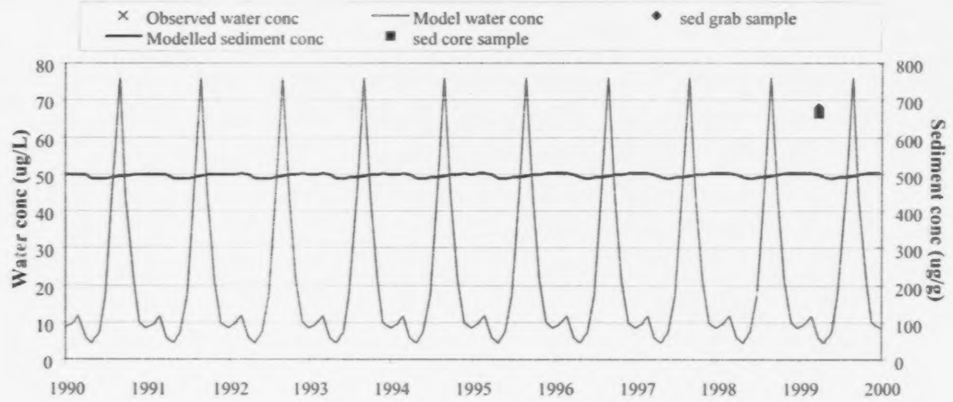


Figure VII-21 Predicted and Observed Nickel Levels in West Moira Lake (1990 to 2000)

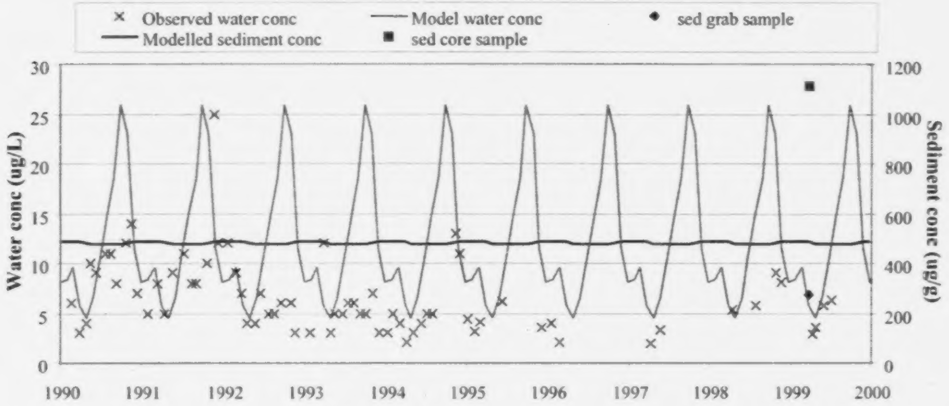


Figure VII-22 Predicted and Observed Nickel Levels in East Moira Lake (1990 to 2000)

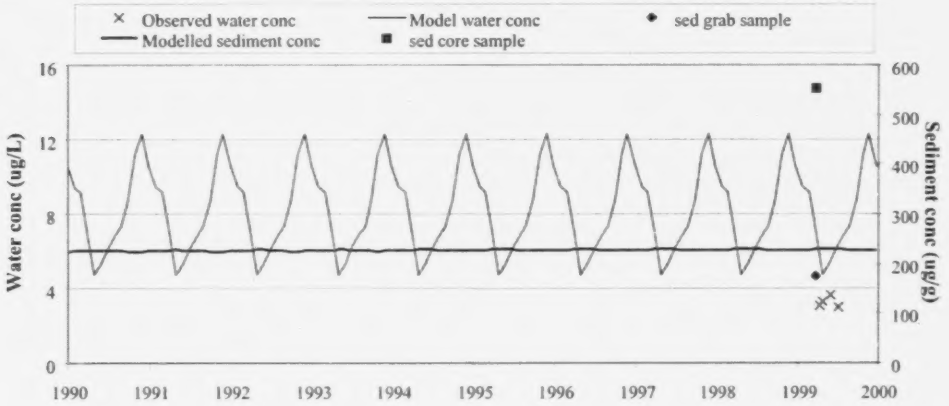


Figure VII-23 Predicted and Observed Nickel Levels in the Moira River from East Moira Lake to Stoco Lake (1990 to 2000)

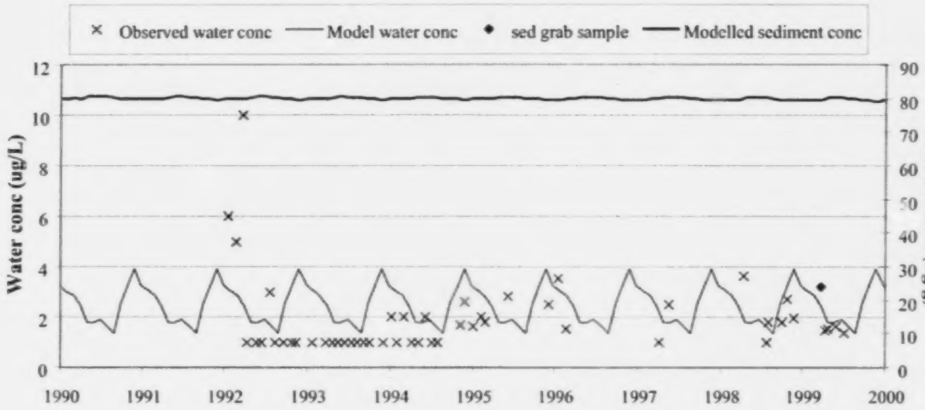
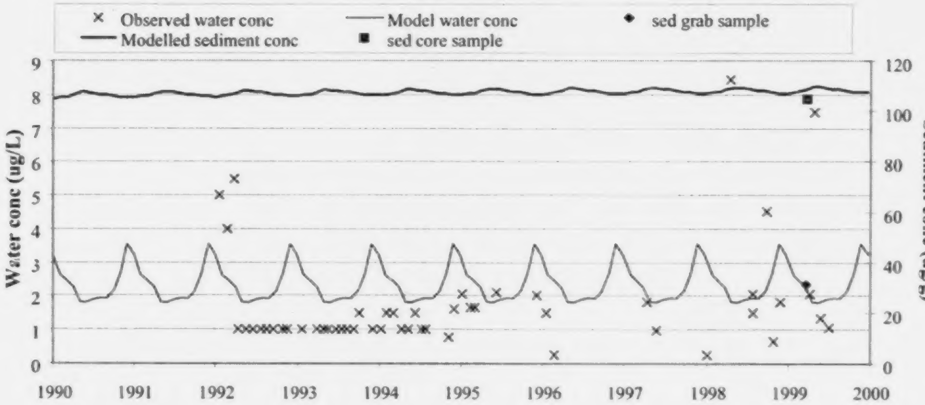


Figure VII-24 Predicted and Observed Nickel Levels in Stoco Lake (1990 to 2000)



APPENDIX VIII

MOE'S REPORT ON YOUNG'S CREEK SEDIMENT RELEASE

Ministry of the Environment

133 Dalton Avenue
P O Box 820
Kingston ON K7L 4X6

Ministère de l'Environnement

133 avenue Dalton
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Kingston ON K7L 4X6

Ontario

Moira River Study
Young's Creek Site Investigation Report
July, 2000

The Moira River study undertaken by Golder Associates for the MOE in 1999, noted that sediments in Young's Creek, above the beaver dams, contained elevated levels of a number of metals and metalloids. Concern was expressed regarding potential release of these sediments, and their contaminant load, to the Moira River due to failure of the beaver dams.

During the weekend of June 24-25, 2000, following a period of heavy rains, failure of sections of a number of beaver dams along Young's Creek was reported. Consequently, Eastern Region and EMRB undertook an inspection of the site to determine the extent of the damage to the beaver dams, and the potential impact of the release of contaminated sediments on the Moira River.

The site visit was conducted on July 10, 2000 by Wayne Herrick (Eastern Region), Rein Jaagumagi (EMRB) and Emily Awad (EMRB). Reports by Wayne Herrick indicated that after failure of the beaver dams, debris had collected at the culvert at Old Marmora Road, blocking the flow with the result that the creek crested and overflowed the road. During the site visit on July 10, the water level was relatively low. There was little evidence of sediments deposited in this area.

Inspection of the beaver dam revealed that a section of the dam approximately 6-7m wide and approximately 1.5 to 2m deep had been removed (Figure 1). At this time, the beavers had already begun to repair the damage to the dam. Comparison of water levels with those occurring immediately after the breach (Herrick, Pers. Comm.), indicated that water levels behind the dam had risen approximately 0.6 to 1.0m. An area of sediment up to 7m out from the base of the beaver dam appeared to have been eroded as a result of the breach of the dam.

Visual inspection indicated that there were likely two sources of contaminated sediments: the material held within the dam structure itself, and the area of sediment adjacent to the dam. The volume of material held within the dam structure was estimated on the basis of the length, depth and width of the section of dam that was removed (8m long, 1.75m high and 3m wide at the base). This would have resulted in the release of approximately 21 m^3 of sediment (~625 ft^3). Since this volume calculation includes the logs and branches used in the construction of the dam, the actual volume of sediment would be less than this estimate.

The area of sediment above the dam would have contributed to a further loss of contaminated sediment. The area eroded was calculated as 8m wide, and up to 7m perpendicular to the dam, for a total of $56m^2$. While such erosion typically assumes a cone-shape, for the purposes of this report, the area has been calculated as a rectangle, so as not to underestimate the area. Visual inspection at the base of the dam indicated that sediment up to 0.6m in depth was eroded. Based on this, the volume of material eroded is calculated as approximately 34 m^3, or 1,000 ft^3. Total volume of sediment lost from this dam due to failure of part of the structure is calculated as $55m^3$ or 1625 ft^3.

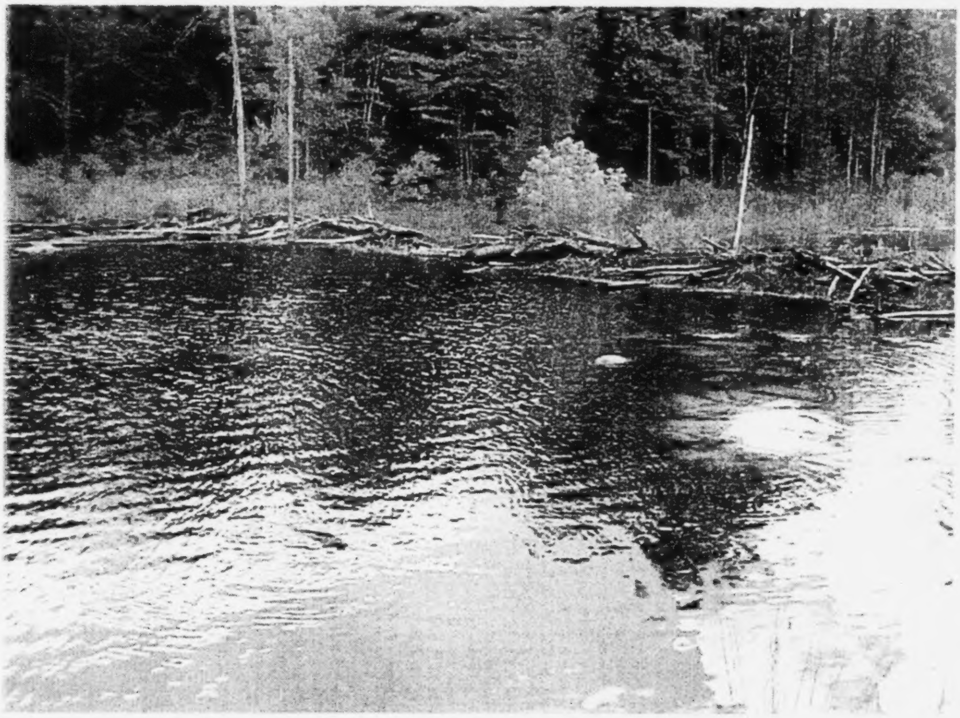
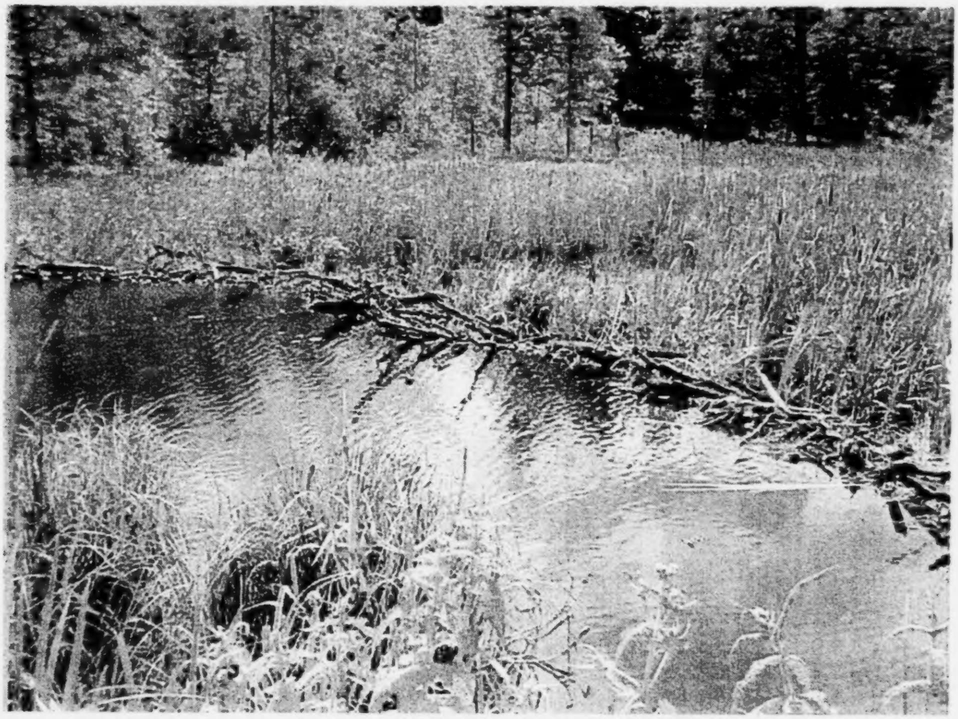


Figure 1: Young's Creek beaver dam above Old Marmora Road July 10, 2000. Area of breach is the low point near the middle of the beaver dam.

Sediment samples were collected from the dam structure, adjacent to the breach, in approximately 0.6m of water. Arsenic levels in these sediments (Table 1) were 650 ppm. Therefore, up to 21 m^3 of sediment with arsenic levels at 650 ppm were released during the breach. In addition, sediments sampled in Young's Creek in 1999 yielded arsenic levels up to 3200 ppm. Based on this, it is estimated that a further 36 m^3 of sediment with arsenic levels up to 3200 ppm were also released.

In addition to the main dam, a secondary dam had been constructed by the beavers approximately 20m downstream. This dam also appeared to have suffered some damage, since there were signs of recent reconstruction of this structure. Below this dam was an extensive area of cattail marsh before the creek reached Old Marmora Road. This area would have served to retard some of the flow from the breach, and the vegetation would have assisted in settling some of the particles released from the dam.

Figure 2: Secondary beaver dam below main dam, with cattail marsh visible downstream, Young's Creek, July 10, 2000.



Sediment samples were collected both above and below Old Marmora Road. In both cases, samples were confined to scraping the top 1cm from the bottom. The results showed an arsenic level of 880 ppm in sediments above the road, and 2300 ppm below the road, just above the confluence with the Moira River. Since samples had not been collected in these locations previously, it cannot be determined if this is due to material released during the dam failures, or due to historical deposition over time.

Sediment samples collected in the Moira River, below Young's Creek at station MR-8, yielded levels of 950 ppm. Sediment were collected adjacent to the river bank, approximately 1m closer than in 1999. This was necessary since fine sediments could not be located in the area previously sampled (most of the sediments in the river appeared to have been scoured by the high flows). Levels of arsenic in sediments in this area of the Moira River in 1999, at 960 ppm were very similar to levels in July, 2000.

In addition, sediment samples were also collected at Bend Bay (station MR- 11). This was identified as the first major depositional area downstream and the most likely area for any significant deposition of materials released from the beaver dams. The arsenic concentration in Bend Bay sediment was 520 ppm in July, 2000. By comparison, arsenic concentration in Bend Bay in 1999 was 660 ppm. The difference is likely due to variation in distribution of arsenic in sediment, since the exact location sampled in 1999 would not have been sampled. What the results do suggest however, is that were was no increase in sediment levels of arsenic due to loss of sediment from behind the beaver dams.

Sediment samples were also collected in two shoreline locations in Moira Lake, one in the west basin and one in the east basin, that were sampled in 1999. The shoreline location in the west basin corresponded to station ML-1A, and would have been between the 1m and 2m depths sampled in 1999. Arsenic concentration at this station was 170 ppm, which compared well with concentrations at the 1m (110 ppm) and 2m (210 ppm) depth in 1999. Since the result of the July 2000 sampling is within this range, there does not appear to have been an increase in sediment arsenic at this location.

The east basin location corresponded to station ML-3A, again between the 1m and 2m depths. Arsenic concentration in the sediment was 47 ppm in July 2000, which was higher than levels encountered in 1999 (8.8 ppm to 17 ppm). However, this may also be due to variation in sediment levels, since the exact locations sampled in 1999 would not have been possible to attain.

In addition to these sediment samples, two additional locations were sampled for sediment arsenic concentrations: Moira River sediments just upstream from the mouth on the west bank of the river (downstream the last recreational property, adjacent to a cattail marsh), and at the 2.5m depth just offshore of the boat launch at Highway 62. Results showed a level of 710 ppm arsenic at the mouth of the river, which is higher than the sediments in Bend Bay. It is unlikely that the relatively small amount of sediment lost from the beaver dams on Young's Creek could have resulted in such levels at the mouth and suggests that these levels are due to historical accumulation of arsenic in sediments. Arsenic levels adjacent to the boat launch are in the range of arsenic concentrations encountered in shoreline areas in the east basin of Moira Lake (8.8 ppm at station ML-3A-1m to 170 ppm at station ML-3B-2m) during the 1999 survey.

The results of the investigation suggest that a minimal amount of sediment was released from the beaver pond during the breach, at that only approximately 55 m^3 of sediment was released to the river. The results of water sampling during this period (by OCWA) indicate there was no increase in arsenic levels in the water column. Some of the released sediment would likely have been retained within the marsh area upstream of Old Marmora Road. It is likely that the small amount of sediment that was released to the Moira River was rapidly diluted, and as downstream sediment results indicate, effected no change in sediment concentrations of arsenic in Bend Bay or nearshore areas of Moira Lake.

Arsenic Concentrations (mg/L) following dam washout at sampling station DM 1 on June 25, 2000

Sample Date	DM 7 - Upstream of Dam	DM 1 - Washout area	DM 8 - Downstream of Dam
June 16, 2000	0.019	0.200	0.098
June 22, 2000	0.023	0.500	**see below
June 25, 2000	no sample	0.336	no sample
June 26, 2000	0.017	0.416	0.064
June 27, 2000	0.018	0.546	0.052
June 28, 2000	0.010	0.298	0.042
July 4, 2000	0.020	0.400	0.190
July 5, 2000	0.024	0.240	0.092

** sample not collected - operator allergic to poison ivy

Historical Results 1997

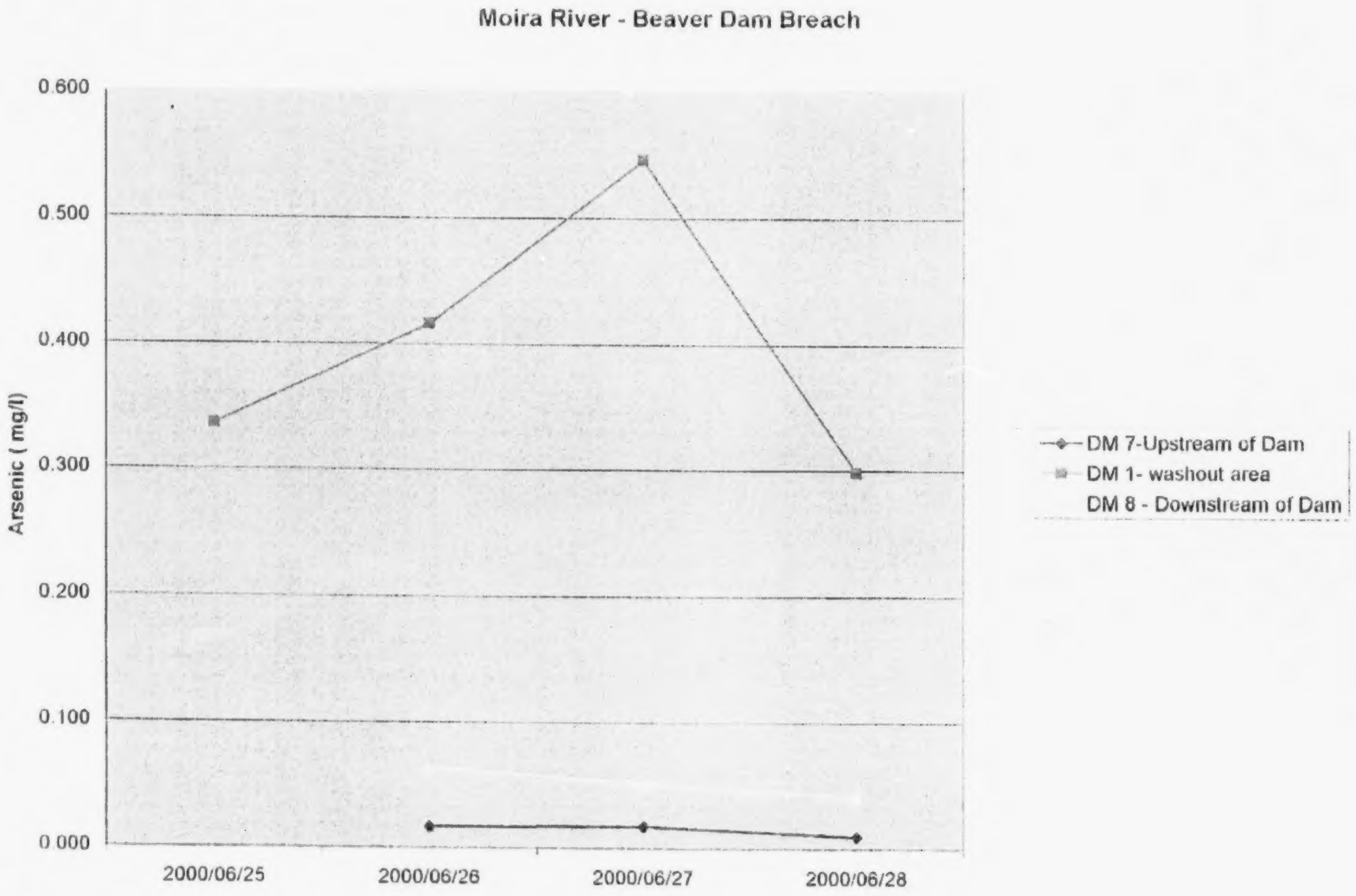
Sample Date	DM 7 - Upstream of Dam	DM 1 - Washout area	DM 8 - Downstream of Dam
June 4, 1997	0.025	0.144	0.028
June 11, 1997	0.040	0.152	0.052
June 18, 1997	0.054	0.142	0.076
June 25, 1997	0.014	0.246	0.044
July 4, 1997	0.019	0.174	0.041
July 10, 1997	0.019	0.126	0.037
July 16, 1997	0.030	0.158	0.036

Historical Results 1998

Sample Date	DM 7 - Upstream of Dam	DM 1 - Washout area	DM 8 - Downstream of Dam
June 4, 1998	0.096	0.222	0.136
June 11, 1998	0.178	0.084	0.172
June 18, 1998	0.082	0.116	0.108
July 2, 1998	0.030	0.384	0.362
July 10, 1998	0.050	0.166	0.134
July 16, 1998	0.062	0.174	0.087

Historical Results 1999

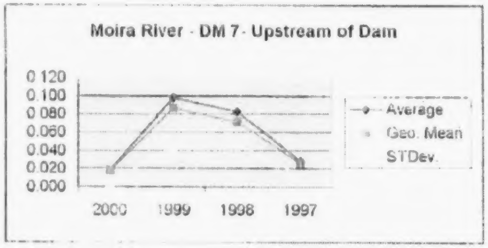
Sample Date	DM 7 - Upstream of Dam	DM 1 - Washout area	DM 8 - Downstream of Dam
June 8, 1999	0.039	0.248	0.062
June 15, 1999	0.058	0.080	0.150
June 24, 1999	0.110	0.142	0.152
June 30, 1999	0.122	0.064	0.164
July 8, 1999	0.162	0.172	0.220


Moira River - Beaver Dam Breach
Arsenic (mg/l)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
2000/06/25
2000/06/26
2000/06/27
2000/06/28
DM 7-Upstream of Dam
DM 1- washout area
DM 8 - Downstream of Dam

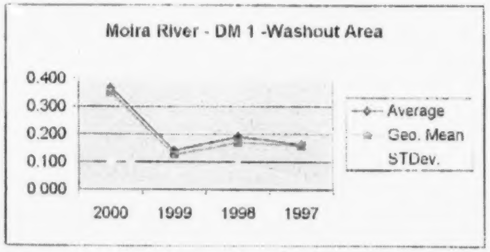
Moira River - Beaver Dam Breach - June 24 / 25, 2000

Arsenic Concentrations (mg/l)

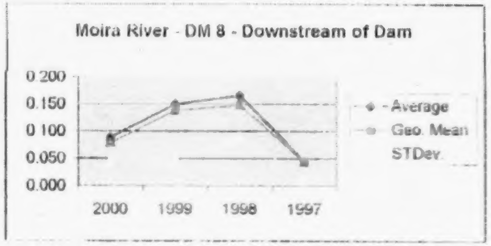
	DM 7- Upstream of Dam			
	2000	**1999**	**1998**	**1997**
Average	0.019	0.098	0.083	0.029
Geo. Mean	0.018	0.087	0.071	0.026
STDev.	0.004	0.044	0.047	0.013
Date of Sampling				
From	16-Jun	8-Jun	4-Jun	4-Jun
To	5-Jul	8-Jul	16-Jul	16-Jul
Number of samples	7	5	6	7



	DM 1- Washout Area			
	2000	**1999**	**1998**	**1997**
Average	0.367	0.141	0.191	0.163
Geo. Mean	0.349	0.125	0.170	0.160
STDev.	0.113	0.066	0.097	0.037
Date of Sampling				
From	16-Jun	8-Jun	4-Jun	4-Jun
To	5-Jul	8-Jul	16-Jul	16-Jul
Number of samples	8	5	6	7



	DM 8 - Downstream of Dam			
	2000	**1999**	**1998**	**1997**
Average	0.090	0.150	0.167	0.045
Geo. Mean	*0.079*	*0.139*	*0.148*	*0.043*
STDev	0.049	0.051	0.091	0.014
Date of Sampling				
From	16-Jun	8-Jun	4-Jun	4-Jun
To	5-Jul	8-Jul	16-Jul	16-Jul
Number of samples	6	5	6	7



Prepared by F.J. Reinholz P.Eng.
Beaver Dam Breach.xls

Table 1: Sediment Metals. Young's Creek and Moira River. July 10, 2000 (in µg/g dry weight unless otherwise noted)

	As	Ba	Cd		Cr	Cu	Fe	Pb		Mn	Ni	Zn	Be		Mg	Al	Ca	Va	Co	Md		St	Ti
YC above dam	650	190	1.8		36	520	20000	25		270	440	180	2.2	<T	4600	17000	9300	37	750	5.1		60	770
YC below dam	160	92	0.6	<T	10	98	13000	8	<T	250	110	57	0.8	<T	2300	7000	4300	13	240	0.9	<T	19	1200
YC above road	880	240	1.4		51	670	32000	35		830	390	160	1.4	<T	8300	19000	9800	48	910	1.5	<T	62	1000
YC below road	2300	320	1.8		67	900	36000	34		1700	560	190	1.5	<T	6200	17000	11000	41	1400	3		66	680
MR below YC	950	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	N.A.
MR Bend Bay	520	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	N.A.
MR mouth	710	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	N.A.
ML west shoreline	170	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	N.A.
ML boat launch	47	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	N.A.
ML east shoreline	47	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.	N.A.		N.A.	N.A.
PSQG:LEL	6	n.a.	0.6		26	16	2	31		460	16	120	n.a.		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.		n.a.	n.a.
PSQG:SEL	33	n.a.	10		110	110	4	250		1100	75	820	n.a.		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.		n.a.	n.a.

N.A. - Not Analyzed n.a. - not available <T - trace levels

APPENDIX IX

MOE LETTERS TO PROPERTY OWNERS

Ontario

November 1999

Dear Property Owner:

As you may know, the Ministry of the Environment has taken several actions to reduce contamination from the abandoned Deloro Mine Site. Since 1983, annual arsenic loading to the Moira River has been reduced by more than 80 per cent. The ministry is currently working on final cleanup plans for the site which will reduce contamination levels further. The cleanup work, which is being planned to begin in the year 2000 construction season, will take about three years to complete at an estimated cost of $18 million. The objective of the remediation work is to deal with the source of contamination, and thereby protect the environment and the health of those living downstream of the mine site.

In addition to the site remediation, and at the request of property owners' associations on Moira and Stoco Lakes, the ministry is conducting a detailed study of the Moira River system. The purpose of the Moira River Study is to assess the environmental impact of contaminants such as arsenic, cobalt, and copper on the river system and to determine whether there is any potential risk to the health of those living downstream. The study area spans from upstream of the Deloro Mine Site to Belleville, and includes Young's Creek, Moira Lake and Stoco Lake.

Extensive sampling of water, sediments, fish and bottom-dwelling organisms is being used to assess the health of the river system. To understand how people are using the river and lakes in the Moira River system, (whether for drinking, bathing, gardening, swimming or cooking), a survey was sent to 625 households in the study area in July 1999. Two hundred and thirty-one households responded. Of those, a few indicated that they take drinking water directly from the Moira River or one of the lakes.

The ministry and the Hastings and Prince Edward Counties Health Unit have contacted these individuals to advise them not to use untreated drinking water from the river system. We would like to take this opportunity to remind property owners that all surface water (lakes, rivers and streams) can contain harmful bacteria and other harmful micro-organisms. It should therefore not be used as a source of drinking water. If you do use surface water, it should first be treated to destroy disease-causing bacteria. A Health Unit information sheet on water treatment is enclosed for your information.

For those living on the Moira River from downstream of Deloro to the outlet of Moira Lake, an additional precaution is recommended. Water sampling to date indicates that levels of arsenic in this area can occasionally exceed the Ontario Drinking Water Objective, particularly during the summer months when water levels are lower In light of this information, and the fact that some people are drinking water directly from the river system, residents taking water from this stretch of the Moira River system are advised, as a measure of prudence, to use another drinking water supply. If you choose to use the river or the lake as your drinking water supply, you should treat the water to remove bacteria and arsenic. Distillation and reverse osmosis are the treatment methods generally recommended for arsenic removal.

The final report of the Moira River Study is targeted for completion in the spring of 2000. Not only will this report provide a snapshot of the state of the environment in the river system, it will also provide information on the significance of the contaminants and recommendations as to further actions which may be required. Findings and recommendations will be communicated to people in the study area.

If you have any questions regarding drinking water from the Moira River system, please contact Dave Dodgson, the Water Quality Coordinator at the Hastings and Prince Edward Counties Health Unit (613) 966-5513 extension 248. For more information on the Moira River Study, contact Wayne Herrick at the Ministry of the Environment 1-800-267-0974 ext. 2678.

Yours truly,

J.G. Ritter

Jim Ritter
Regional Project Manager
Ministry of the Environment
Kingston

Glen Hudgin

Glen Hudgin
Director of Public Health Inspection
Hastings and Prince Edward Counties
Health Unit
Belleville

Ontario

November 1999

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J.G. Ritter

Jim Ritter
Regional Project Manager
Ministry of the Environment
Kingston

Glen Hudgin

Glen Hudgin
Director of Public Health Inspection
Hastings and Prince Edward Counties
Health Unit
Belleville

APPENDIX X

UPDATED PQRA:

ASSESSMENT OF RISKS TO HUMAN HEALTH FROM EXPOSURE TO SEDIMENTS IN STUDY AREA A (DELORO MINE SITE TO THE INLET OF MOIRA LAKE)

Distribution:

2 Copies -	Ministry of Environment, Kingston, Ontario
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1.0 INTRODUCTION

This Updated Preliminary Quantitative Risk Assessment (PQRA) was produced in response to the findings of the PQRA presented in the Technical Report of the Phase II Moira River Study (Golder, 2000). The original PQRA was a conservative, screening level assessment. It was used to determine whether there are potential current and future human health risks associated with substances released to the Moira River system from the Deloro Mine Site. The results of the PQRA were used to determine whether a more detailed risk assessment was needed.

The PQRA considered how users of the river system might come into contact with metals present in water, sediments and fish and then compared estimated exposures to benchmark values that represent safe or acceptable exposure levels. The PQRA used conservative assumptions to estimate exposure. Therefore, the exposure estimates were "worst case", and are likely to overestimate true exposure levels and associated risks. If the “worst case” exposure estimates were below the benchmark values, then there was a high level of confidence that the exposure pathways and metal concentrations being considered did not require further assessment. If the “worst case” exposure estimates were above the benchmark values, then further assessment of those particular pathways and metals was indicated.

The PQRA showed that all estimated exposures to the metals of concern were below benchmark values except for arsenic in Study Area A (Deloro Mine Site to the inlet of Moira Lake) and Study Area B (Moira Lake). The PQRA indicated that residents of Study Areas A and B would have greater estimated levels of exposure to arsenic than the Typical Ontario Resident (TOR) under the conditions assumed in the assessment. Use of water from the river system for drinking water was the most significant pathway of exposure to arsenic. The drinking water reminder issued by the MOE and the Hastings and Prince Edward Counties Health Unit (Appendix IX) was and continues to be appropriate.

Exposure to sediments in Study Area A was another exposure pathway that produced estimated exposures above benchmark values. This section of the river is not well suited for in-water recreational activities and has only a limited number of residences. However, recreational use of this section of the river system may be an important exposure pathway, at least for some individuals. The amount of exposure through this pathway, both in absolute terms and relative to total arsenic exposure, required further study.

The overall goal of this Updated PQRA was to determine whether exposure to sediments in Study Area A contributes significantly to potential risk to persons who come into contact with these sediments. The results would indicate whether specific risk management options for sediments are required.

1.1 Scope of Work

The scope of work for this Updated PQRA is to assess the potential risk to recreational users of the Moira River in Study Area A associated with exposure to arsenic in sediment.

1.2 Study Approach

The Updated PQRA was completed using similar methodology and assumptions adopted for the PQRA, as discussed in Section 3 of the Technical Report. However, this Updated PQRA was focused on locations where children actually used the river for recreational activities such as swimming and wading, whereas the initial PQRA addressed sediment quality at representative downstream locations. To evaluate potential health risks, this assessment considers the following three exposure and toxicological effects endpoints.

- Acute Effects: *(effects other than cancer that occur after a short-term exposure duration, usually defined in hours or days)*
- Chronic and Subchronic Non-Cancer Effects: *(effects other than cancer that occur after a medium to long-term exposure duration, usually defined in months or years)*
- Chronic Cancer Effects: *(cancer effects are associated with a long-term exposure duration, usually defined in years or lifetime)*

It was necessary to evaluate all three of these endpoints to ensure that the potential risks to individuals exposed to arsenic in sediment in Study Area A were considered. A difference between the PQRA (as contained in the Moira River Study report) and the Updated PQRA, is that the PQRA focused on chronic and subchronic non-cancer effects and chronic cancer effects, whereas the Updated PQRA also evaluated acute effects from sediment exposure. A discussion of the specific approach adopted for this updated assessment is described in the following sections.

2.0 SEDIMENT SAMPLING AND ANALYSIS

A supplemental sediment sampling survey was conducted by Golder Associates during the period July 31 to August 3, 2000, to identify access points and potential locations for swimming/bathing/wading along the Moira River within Study Area A. The results of this survey have been compiled and included with the results from the initial sediment sampling program, as discussed in Section 2.1.2 (Results). A complete discussion of the previous sediment sampling program is presented in Section 2.2 of the Technical Report (Golder, 2000).

It should be noted that only "near-shore" sample locations, defined as locations with 1 m or less water depth, were included in this assessment. The selection of shallow water depths is related to the choice of a child aged 5 - 11 as the receptor most likely to have the highest exposures. The rationale for the choice of a child receptor is presented in Section 3.2 (below).

2.1 Methods

Supplemental sediment sampling locations within Study Area A were selected based on a combination of factors that influence the potential for resident and cottager exposure to sediments. These include:

- public or cottage access;
- water depth;
- substrate type; and
- evidence of recreational use.

All near-shore recreational activities and evidence of recreational use (docks, boats, beaches, swimming platforms, rope swings, etc.) were noted and photographed. Use of an area by children was of particular importance. This use was evidenced by swing sets or playgrounds on shore and toys or children heard or seen playing either on land or in the water. Most of these indications of use were observed during the collection of sediment samples.

Sediment samples were collected from water depths less than 1 meter using a Petite Ponar grab sampler deployed from a small boat. Three grab samples were taken at each site and combined in roughly equal proportions in a large stainless steel bowl. Vegetation fragments, woody debris and any large stones were removed. A sub-sample was then placed into glass jars for submission under chain of custody to Philip Analytical Services for analysis of total arsenic concentrations. Depth, substrate characteristics and current velocities were also recorded at each sampling location.

Sediment samples were collected from nine locations (designated as locations 1 through 9) between Bronson's Rapids (Location 1) and the inlet to Moira Lake (Location 9) (see Figure 1). The nine sample locations for the supplemental sampling program were sampled in areas that consisted exclusively of private access areas and varied from sand beaches to marshy shorelines. The area upstream of Bronson's Rapids was not sampled because there were very few access points and there was an abundance of poison ivy in the area. Thus, it is unlikely that this area of the river would be used for swimming.

2.2 Analytical Results

Total arsenic concentrations in the supplemental sediment samples ranged from 10.2 mg/kg to 238.0 mg/kg (Table 1). Four samples contained greater than 50% fine organic sediments, with total arsenic concentrations ranging from 141.0 mg/kg to 232 mg/kg. Two sites had between 39 and 50% fine sediments. Arsenic concentrations at these sites were 95.0 mg/kg and 200.0 mg/kg. Three sites (RAMR-A-5, RAMR-A-7 and RAMR-A-9) contained less than 20% fine sediments and the total arsenic concentrations at these stations ranged from 10.2 mg/kg to 25.4 mg/kg.

The sediment samples collected at water depths less than 1 metre during the first sampling program in 1999 were not used in this assessment. These sites are in the section of the river that has very few access points and abundant poison ivy along the banks. Use of the river for recreational purposes is highly unlikely in this portion of the river.

Figure 1
Sediment Sampling Locations in Study Area A

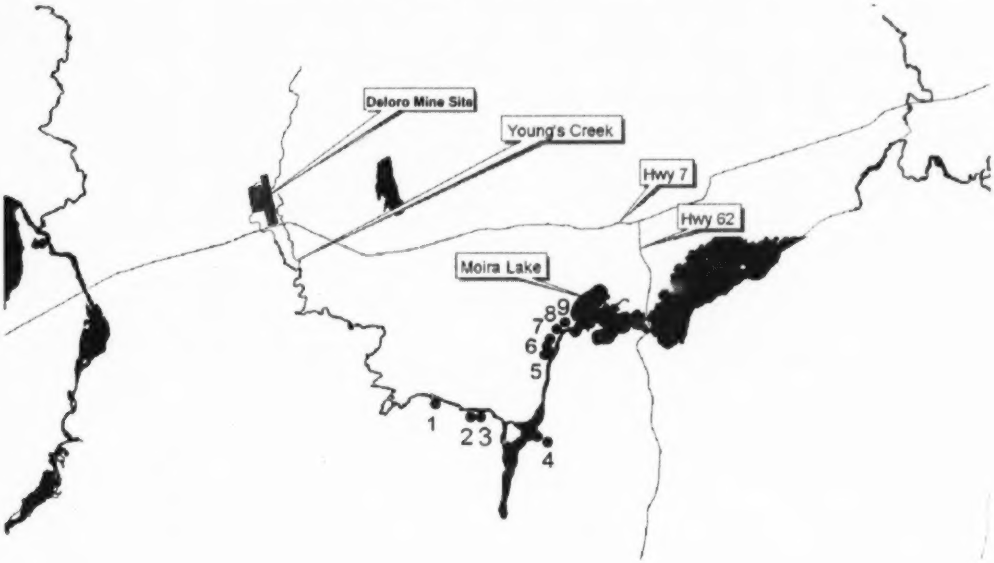

TABLE 1

Arsenic Concentrations Detected at Study Area A Sampling Sites

Station Number	Sampling Event	Total Arsenic (mg/kg)	Percent Fines[1]	Location
RAMR-A-1	2	208.0	79.2	Single cottage near Bronson's Rapids
RAMR-A-2	2	141.0	57.6	Single cottage about 2 km upstream of Bend Bay
RAMR-A-3	2	232.0	88.9	Single cottage about 2 km upstream of Bend Bay
RAMR-A-4	2	95.0	39.0	Private access[2] on B[illegible] Bay
RAMR-A-5	2	10.2	2.5	Group of 6 cottages about 2.6 km below Bend Bay
RAMR-A-6	2	200.0	60.1	Group of 6 cottages about 2.6 km below Bend Bay
RAMR-A-7	2	25.4	18.5	Group of 2 cottages about 3 km below Bend Bay
RAMR-A-8	2	238.0	49.1	Single cottage about 0.4 km upstream of inlet to Moira Lake
RAMR-A-9	2	11.6	10.3	Group of 3 cottages about 0.2 km upstream of inlet to Moira Lake
Highest Concentration		**238.0**		
Average Concentration		**129.0**		

[1] equals percent silt and percent clay.

[2] probably private access point, but no cottage observed.

The average arsenic concentration of 129 mg/kg in sediment samples from the supplemental sampling program was used in the exposure assessment in the Updated PQRA. Use of this value is appropriate for the exposure assessment because it is representative of the sediment quality in Study Area A at areas where known human access to the river occurs. In addition, modelling using the maximum arsenic concentration of 238 mg/kg was also employed to represent a "worst case" exposure scenario.

3.0 PRELIMINARY QUANTITATIVE RISK ASSESSMENT

The Updated PQRA is a semi-quantitative evaluation of the potential risk to human health resulting from exposure to arsenic present in sediments from Study Area A. The methodology and assumptions adopted for this assessment are similar to those used in the PQRA, as described in Section 3 of the Technical Report.

A deterministic modelling approach has been adopted for this Updated PQRA. Health-protective point estimates for all parameters used to describe exposure and toxicity have been incorporated into this assessment. For example, maximum plausible estimates of receptor characteristics including body weight, body surface area and water consumption have been used. This approach is expected to result in exposure estimates that are greater than what actually occurs. In addition, both maximum and average arsenic concentrations were considered.

3.1 Exposure Assessment

The exposure assessment describes and quantifies how humans may come into contact with arsenic in sediments from Study Area A. Considering that people may reside on the river system all year and may come into contact with arsenic in sediments, various potential pathways of exposure were examined.

As described above, the average concentration of arsenic in sediments from Study Area A collected at depths of 1 metre or less was used for the exposure modelling (Table 1). Use of these shallow water sediment samples is appropriate since it is considered unlikely that a child aged 5 - 11 (i.e., the receptor) will come into contact with sediments at depths much greater than 1 metre. Exposure was estimated using sediment concentrations, along with receptor body weight, ingestion rate, dermal contact rate, time activity patterns (i.e., time spent swimming) and chemical bioavailability.

Table 2 is a summary of the exposure pathways that have been considered to be important for this assessment.

TABLE 2
Exposure Pathways

Environmental Matrix	Description of Exposure Pathway	Pathway Number
Shallow Water Sediment	Accidental ingestion during recreational activities	1
Shallow Water Sediment	Dermal contact during recreational activities	2

Equations and a detailed description of the input variables that were used for the exposure modelling for these two pathways are given in Table 3 (acute effects), Table 4 (chronic non-cancer health effects) and Table 5 (cancer effects).

TABLE 3
Exposure Pathway Equations and Input Variables for Acute Effects

Exposure Pathway	Description of Exposure	Exposure Pathway Calculations			Value
1	**Accidental ingestion of sediment**	**AIS**	=	**[SI x CS x OB] / BW**	
	where:	AIS	=	Accidental ingestion of sediment (µg/kg/day)	Calculated
		SI	=	Sediment ingestion (g/day)	see Tables 6 and 7
		CS	=	Arsenic concentration in sediment (µg/g)	129 or 238 µg/g
		OB	=	Oral bioavailability (unitless)	See Table 10
		BW	=	Body weight (kg)	32.9 kg
2	**Dermal contact with sediment**	**DSE**	=	**[C x A x BF x 10-3] / BW**	
	where:	DSE	=	Dermal sediment exposure (µg/kg/day)	Calculated
		C	=	Arsenic concentration in sediment	129 or 238 µg/g
		A	=	Soil adherence	see Tables 6 and 7
		BF	=	Bioavailability factor	See Table 10
		BW	=	Body weight (kg)	32.9 kg

The dose estimates calculated using these equations identify the daily dose of arsenic that the child receptor receives. Comparison of this dose estimate to the acute toxicity reference value for arsenic will determine whether the receptor may be expected to experience acute arsenic toxicity effects.

Arsenic can also cause chronic and sub-chronic non-cancer health effects in humans. To determine the potential for these types of adverse effects to arise in exposed individuals, it is necessary to calculate the average daily dose, occurring in any given year. The equations and a detailed description of the input variables that were used for the exposure modelling for the two exposure pathways are given in Table 4 (chronic and sub-chronic non-cancer endpoints).

TABLE 4
Exposure Pathway Equations and Input Variables for Chronic and Sub-Chronic Non-Cancer Effects

Exposure Pathway	Description of Exposure	Exposure Pathway Calculations			Value
1	**Accidental ingestion of sediment**	**AIS**	=	**[SI x CS x OB] x EF x ED/ BW x AT**	
	where:	AIS	=	Accidental ingestion of sediment (µg/kg/day)	Calculated
		SI	=	Sediment ingestion (g/day)	see Tables 6 and 7
		CS	=	Arsenic concentration in sediment (µg/g)	129 or 238 µg/g
		OB	=	Oral bioavailability (unitless)	See Table 10
		EF	=	Exposure Frequency	60 or 14 days
		ED	=	Exposure Duration	7 years
		BW	=	Body weight (kg)	32.9 kg
		AT	=	Averaging Time	7 years
2	**Dermal contact with sediment**	**DSE**	=	**[C x A x BF x 10^{-3}] x EF x ED / BW x AT**	
	where:	DSE	=	Dermal sediment exposure (µg/kg/day)	Calculated
		C	=	Arsenic concentration in sediment	129 or 238 µg/g
		A	=	Soil adherence	see Tables 6 and 7
		BF	=	Bioavailability factor	See Table 10
		EF	=	Exposure Frequency	60 or 14 days
		ED	=	Exposure Duration	7 years
		BW	=	Body weight (kg)	32.9 kg
		AT	=	Averaging Time	7 years

Since arsenic can cause cancer, it is necessary to estimate the average daily dose of arsenic to which a person is exposed over an entire lifetime. This dose, termed the Lifetime Average Daily Dose (LADD), is multiplied by the cancer potency factor for arsenic to estimate the associated increased cancer risk. Equations and a detailed description of the input variables that were used for the exposure modelling for these two pathways are given in Table 5 (cancer endpoints).

Table 5

Exposure Pathway Equations and Input Variables for Cancer Assessment

Exposure Pathway	Description of Exposure	Exposure Pathway Calculations			Value
1	**Accidental ingestion of sediment**	**AIS**	=	**([SI x CS x OB x F] / (BW x AT)**	
	Where:	AIS	=	Accidental ingestion of sediment (µg/kg/day)	Calculated
		SI	=	Sediment ingestion (g/day)	See Tables 6 and 7
		CS	=	Arsenic concentration in sediment	129 or 238 µg/g
		OB	=	Oral bioavailability (unitless)	See Table 10
		F	=	Frequency of events	See Tables 6 and 7
		AT	=	Averaging time	365 days
		BW	=	Body weight (kg)	See Tables 8 and 9
2	**Dermal contact with sediment**	**DSE**	=	**([C x A x BF x 10-3 x F] / (BW x AT)**	
	where:	DSE	=	Dermal sediment exposure (µg/kg/day)	Calculated
		C	=	Arsenic concentration in sediment	129 or 238 µg/g
		A	=	soil adherence	See Tables 6 and 7
		BF	=	bioavailability factor	See Table 10
		F	=	frequency of events	See Tables 6 and 7
		AT	=	averaging time	365 days
		BW	=	body weight (kg)	See Tables 8 and 9

3.2 Receptor Selection

3.2.1 Non-Cancer Endpoints

For the assessment of non-cancer endpoints, a child aged 5 to 11 years old was identified as the most appropriate human receptor to evaluate potential non-cancer effects. This age group was selected for the receptor because the physical characteristics and activity patterns for children of this age make them the most likely to have the greatest exposure on a body weight basis. For example, they generally spend more time outdoors swimming and playing along the river and lakes than either adults or younger children, and are expected to have higher levels of exposure on a body weight basis due to their physical characteristics. Therefore, use of this receptor represents a health-protective approach to the Updated PQRA.

This assessment considered two different receptor scenarios, as summarized below:

- ***Receptor Scenario 1:*** This scenario represents a resident child receptor that swims in the Moira River in Study Area A for 60 days each year. The child receptor characteristics for this scenario are identical to those identified in the PQRA, as discussed in the Technical Report.

- ***Receptor Scenario 2:*** This scenario represents a child receptor that vacations for a two week period in Study Area A and uses the river for swimming over this period. For this scenario, it is assumed that the child receptor uses the river more intensively over the two-week period. Therefore, this receptor is assumed to have a 50 percent higher sediment ingestion rate and a 25 percent higher soil adherence factor than Receptor Scenario 1 because of more time spent in the water per day. Receptor Scenario 2 was selected to reflect the differences in activity and exposure patterns associated with a short, but intense, use of the river.

Parameters describing the physiological and behavioral characteristics of the child receptor for each of the two receptor scenarios are given in Table 6 (Scenario 1) and Table 7 (Scenario 2). Maximum plausible receptor characteristics such as ingestion rate and body surface area were employed and are expected to overestimate actual exposure in most cases.

TABLE 6
Receptor Characteristics – Scenario 1

Characteristic	**Child (5-11 years)**
Body Weight	32.9 kg
Sediment Ingestion	0.2 g/day
Sediment Adherence Factor	10 g/m^2/day
Exposed Skin in Summer	0.784 m^2
Total Surface Area	1.35 m^2
Swimming Events	60 day/year

TABLE 7
Receptor Characteristics – Scenario 2

Characteristic	Child (5-11 years)
Body Weight	32.9 kg
Sediment Ingestion	0.3 g/day
Sediment Adherence Factor	12.5 g/m^2/day
Exposed Skin in Summer	0.784 m^2
Total Surface Area	1.35 m^2
Swimming Events	14 day/year

The exposure rates in Tables 6 and 7 were selected to represent a reasonable "worst case" exposure scenario. The number of swimming events for Scenario 1 (60 days) was an assumed value selected to represent the maximum number of days that a child is expected to swim in the river during the summer. For Scenario 2, the number of days was selected to represent a two-week period for a family that uses the river while on summer vacation.

3.2.2 Cancer Endpoints

To estimate the risk of cancer, arsenic exposures were estimated based on a lifetime of exposure over four discrete life stages (i.e., preschool child, child, adolescent and adult). The physiological and behavioral characteristics of each life stage used for the exposure modelling are given in Tables 8 and 9.

TABLE 8
Receptor Characteristics (Cancer) – Scenario 1

Characteristic	Preschool Child	Child (5-11 years)	Adolescent	Adult
Body Weight	16.5 kg	32.9 kg	59.7 kg	70.7 kg
Sediment Ingestion	0.2 g/day	0.2 g/day	0.1 g/day	0.1 g/day
Sediment Adherence Factor	10 g/m^2/day	10 g/m^2/day	10 g/m^2/day	10 g/m^2/day
Exposed Skin in Summer	0.463 m^2	0.784 m^2	1.16 m^2	1.22 m^2
Total Surface Area	0.799 m^2	1.35 m^2	1.94 m^2	2.13 m^2
Swimming Events	60 day/year	60 day/year	60 day/year	60 day/year

Table 9
Receptor Characteristics (Cancer) – Scenario 2

Characteristic	Preschool Child	Child (5-11 years)	Adolescent	Adult
Body Weight	16.5 kg	32.9 kg	59.7 kg	70.7 kg
Sediment Ingestion	0.3 g/day	0.3 g/day	0.15 g/day	0.15 g/day
Sediment Adherence Factor	12.5 $g/m^2/day$	12.5 $g/m^2/day$	12.5 $g/m^2/day$	12.5 $g/m^2/day$
Exposed Skin in Summer	0.463 m^2	0.784 m^2	1.16 m^2	1.22 m^2
Total Surface Area	0.799 m^2	1.35 m^2	1.94 m^2	2.13 m^2
Swimming Events	14 day/year	14 day/year	14 day/year	14 day/year

3.3 Toxicity Assessment

The toxicological criteria and bioavailability factors used in this assessment were adopted from the PQRA (Golder 2000), and were derived from the environmental health risk assessment conducted for the Village of Deloro (CanTox 1999). Table 10 is a summary of the toxicological criteria and the bioavailability factors for arsenic. Regulatory agencies such as Health Canada and the US EPA have developed these values. A description of the toxicological properties of arsenic is given elsewhere (CanTox 1999 and Golder, 2000).

TABLE 10
Toxicological Criteria and Sediment Bioavailability Factors for Arsenic

Endpoint	Route	Criterion/ Value	Effect	Study	Agency
Acute effects	Oral	PMTDI 2 µg/kg/day	acute arsenic intoxication such as abdominal pain, vomiting, muscular pain and weakness	Joint FAO/WHO Expert Committee on Food Additives	JECFA 1989
Non-cancer	Oral	RfD 0.3 µg/kg/day	hyperpigmentation, keratosis, possible vascular complications (human)	Tseng et al., 1968 Tseng, 1977	US EPA 1998
Cancer	Oral	q_1^* 0.0015 $(\mu g/kg/day)^{-1}$	skin cancer, basal and squamous cell carcinoma (human)	Tseng et al., 1968 Tseng, 1977	US EPA 1998
Bioavailability	Dermal	0.8 – 1.9 percent	NA	Webster et al., 1993	NA
Bioavailability	Oral (sediment)	14 percent (soil)	NA	Freeman et al., 1995	NA

NA: not applicable
Information adopted from CanTox (1999) and Golder (2000).

3.4 Risk Characterization

Risk characterization is the final step in the Updated PQRA and involves comparing the estimated exposures to exposure values that are safe. Comparison of the estimated exposures to arsenic to those typically encountered by the general population is also an important aspect of risk characterization, since it provides a frame of reference to evaluate local conditions. Finally, uncertainties in the assessment, and their impact on its conclusions, are identified and discussed.

3.4.1 Acute Effects

Acute exposure to elevated levels of arsenic is associated with various effects including abdominal pain, vomiting, muscular pain and weakness. To characterize the potential risks associated with acute arsenic exposure it is necessary to compare the estimated daily dose (i.e., exposure) to a health-protective toxicity reference value. For this assessment, the Provisional Maximum Tolerable Daily Intake Value (PMTDI) of 2 µg/kg/day, which was originally derived by the FAO/WHO Joint Expert Committee on Food Additives, was selected as the appropriate toxicity reference value (JECFA, 1989). This is the same value that was adopted as an acute toxicity reference value for the environmental health risk assessment conducted for the Village of Deloro (Cantox, 1999). To determine whether there is a potential for acute effects, an Exposure Ratio (ER) is calculated by dividing the estimated exposure by the PMTDI, as summarized below.

$$\textit{Exposure Ratio} = \frac{\textit{Estimated Exposure}}{\textit{PMTDI}}$$

ER values less than one indicate that no acute adverse effects are expected. Conversely, ER values greater than one may indicate a health risk.

The estimated acute exposure to arsenic present in sediments from Study Area A and the calculated ERs for each of the two receptor scenarios is given in Table 11 (calculated based on the average arsenic concentration) and Table 12 (calculated based on the maximum detected arsenic concentration).

TABLE 11
Estimated Arsenic Exposure Levels and Exposure Ratios for Acute Effects (Average)

Exposure Pathway	Exposure Pathway Description	Receptor 1	Receptor 2
1	Accidental ingestion of sediment	0.22	0.33
2	Dermal contact with sediment	0.10	0.13
	Total exposure for pathways 1 – 2 (µg/kg/day)	**0.32**	**0.46**
Provisional Maximum Tolerable Daily Intake (PMTDI) in µg/kg/day		2	2
Exposure Ratio		**0.16**	**0.23**

The calculated ER values for acute effects are approximately 0.2 for both receptor scenarios, which are well below the level at which health effects may be observed (i.e., ER value equal to 1).

The ER values for Receptor Scenarios 1 and 2 using the maximum observed arsenic concentration of 238 mg/kg are 0.3 and 0.4, respectively (Table 12). These ER values are less than half the value at which there is a potential risk of acute health effects.

TABLE 12
Estimated Arsenic Exposure Levels and Exposure Ratios for Acute Effects (Maximum)

Exposure Pathway	Exposure Pathway Description	Receptor 1	Receptor 2
1	Accidental ingestion of sediment	0.41	0.61
2	Dermal contact with sediment	0.19	0.24
	Total exposure for pathways 1 – 2 (µg/kg/day)	**0.60**	**0.85**
Provisional Maximum Tolerable Daily Intake (PMTDI) in µg/kg/day		2	2
Exposure Ratio		**0.3**	**0.4**

The ER values for Receptor Scenarios 1 and 2 in Tables 11 and 12 do not consider exposure to arsenic from other pathways. The Typical Ontario Resident (TOR) is exposed to arsenic via food and other sources. Therefore, any arsenic exposures received by residents in Study Area A because of contact with sediments would be incremental (in addition) to exposures received as a TOR.

Exposure of the residents of Study Area A via other pathways may be evaluated based on the exposures received by the TOR. The ER values calculated for the TOR are representative of the health risks typically encountered by the average Ontario resident and were calculated using standard risk assessment methodology. As outlined in the environmental health risk assessment for the Village of Deloro, the estimated daily exposure to arsenic from all sources is approximately 0.6 µg/kg/day for the 50th percentile TOR and approximately 1.4 µg/kg/day for the 95th percentile TOR (CanTox, 1999). The estimated total exposure from sediments and other exposure pathways for the 50th and 95th percentile TOR are discussed below.

Total Exposures Using the 50th Percentile TOR:

Residents or users of the river in Study Area A would have a total estimated daily exposure to arsenic of 1 and 1.1 µg/kg/day for Receptor Scenarios 1 and 2, respectively. This total exposure estimate is based upon the average arsenic sediment concentration in Study Area A and the 50th percentile TOR exposure value. The resulting acute health risk ER value for both scenarios is approximately 0.5. The ER value assuming the maximum arsenic sediment concentration of 1.23 µg/kg/day is 0.6 for Receptor Scenario 1 and 0.7 for Receptor Scenario 2. All ER values for the 50th percentile TOR plus exposure to sediments in Study Area A are less than 1. Thus, the incremental exposure to arsenic in sediments from Study Area A does not represent an acute health risk.

Total Exposures Using the 95th Percentile TOR:

The total estimated daily arsenic intake is approximately 1.7 and 1.9 µg/kg/day for Receptor Scenarios 1 and 2, respectively if the 95th percentile TOR exposure value and average arsenic sediment concentration are assumed. The corresponding ER values for both scenarios are 0.9. If the maximum arsenic sediment concentration is used, then the cumulative estimated exposure for Receptor Scenario 1 is 2 µg/kg/day and 2.3 µg/kg/day for Receptor Scenario 2. The corresponding ER values for both scenarios are 1. The cumulative exposure values calculated for the 95th percentile TOR, which may be considered a "worst case" scenario, are approximately 1. In light of the conservative nature of the assessment, residents and users of the Moira River in Study Area A are unlikely to experience acute health effects due to exposure to arsenic.

In summary, the above findings indicate that the concentrations of arsenic detected in sediment in Study Area A are not expected to represent an acute health risk to area residents and other users of the river, even under worst case exposure conditions and considering exposure to arsenic from other sources. However the margin of safety between the predicted exposure values and the acute toxicity reference value may be small.

3.4.2 Chronic Non-Cancer Endpoints

Non cancer effects do not occur after chronic or sub-chronic exposure unless the dose is above a certain threshold. Risk characterization for these chemicals involves comparing the total estimated daily dose (i.e., exposure) to the Reference Dose (RfD). The RfD defines the amount of chemical that humans, including sensitive sub-populations, may be exposed to on a daily basis for an entire lifetime without an adverse effect. To determine the potential for chronic and sub-chronic non-cancer health effects, the ER was calculated by dividing the estimated exposure by the RfD, as summarized below.

$$\textit{Exposure Ratio} = \frac{\textit{Estimated Exposure}}{\textit{RfD}}$$

As described above, ER values less than one indicate that no adverse effects are expected whereas ER values greater than one may indicate a health risk. However, because of the conservative approach used in this assessment, ER values greater than one may not represent a significant risk. In these instances, additional interpretation of the results is needed.

The estimated exposure to arsenic present in sediments from Study Area A and the calculated ERs based on these exposure estimates for each of the two receptor scenarios is given in Table 13 (calculated based on average arsenic concentrations) and Table 14 (calculated based on maximum detected arsenic concentrations).

TABLE 13
Arsenic Exposure Levels and Exposure Ratios for Chronic Non-Cancer Health Effects (Average)

Exposure Pathway	**Exposure Pathway Description**	**Receptor 1**	**Receptor 2**
1	accidental ingestion of sediment	0.04	0.01
2	dermal contact with sediment	0.02	0.01
	Total exposure for pathways 1 – 2 (μg/kg/day)	**0.06**	**0.02**
	Reference Dose (RfD) in μg/kg/day	0.30	0.30
	Exposure Ratio	**0.2**	**0.1**

As shown in Table 13, the calculated ER values based on average arsenic sediments concentrations are significantly less than one for both exposure scenarios. This result indicates that adverse chronic non-cancer health effects in residents and other users of the river system exposed to arsenic in sediment in Study Area A are not expected.

ER values calculated based on the maximum concentration of arsenic detected in sediment are 0.3 and 0.1 for Receptor Scenarios 1 and 2, respectively (see Table 14). These ER values are both considerably less than 1 and suggests that adverse chronic non-cancer health effects in individuals exposed to the sediments are unlikely.

TABLE 14
Arsenic Exposure Levels and Exposure Ratios for Chronic Non-Cancer Health Effects (Maximum)

Exposure Pathway	**Exposure Pathway Description**	**Receptor 1**	**Receptor 2**
1	Accidental ingestion of sediment	0.07	0.02
2	Dermal contact with sediment	0.03	0.01
	Total exposure for pathways 1 – 2 (μg/kg/day)	**0.10**	**0.03**
	Reference Dose (RfD) in μg/kg/day	0.30	0.30
	Exposure Ratio	**0.3**	**0.1**

As discussed previously, the ER values for Receptor Scenarios 1 and 2 do not consider exposure to arsenic from other pathways. To determine the significance of the above findings when other sources of exposure to arsenic are considered, the estimated ER values were compared to ER values for arsenic calculated for the 50th percentile TOR and 95th percentile TOR as described elsewhere (Cantox, 1999).

Total Exposures Using the 50th Percentile TOR:

The total estimated arsenic exposures for a 50th percentile TOR using the average arsenic sediment concentration in Study Area A are 0.7 and 0.6 µg/kg/day for Receptor Scenario 1 and 2, respectively. The corresponding ER values are 2 for Receptor Scenarios 1 and 2. These values are not significantly different than the ER value of 2 calculated for the 50th percentile TOR. Therefore, exposure to sediments in Study Area A does not represent a significant exposure pathway, relative to other sources of exposure experienced by the TOR. Residents of Study Area A who use the river for swimming or bathing would not receive a significant incremental exposure to arsenic compared to the TOR.

Total Exposures Using the 95th Percentile TOR:

Residents of Study Area A who use the river for swimming or bathing would not be exposed to more arsenic than the 95th percentile TOR. The total estimated cumulative arsenic exposures using the 95th percentile TOR and the average arsenic concentration are 1.5 µg/kg/day and 1.4 µg/kg/day for Receptor Scenario 1 and 2, respectively. The corresponding exposure values for Receptor Scenarios 1 and 2 are 5. Since the ER value for the 95th percentile TOR is 5, this result indicates that exposure to maximum arsenic concentrations in sediments from Study Area A does not represent a significant exposure pathway relative to other sources of exposure experienced by the TOR.

The ER values for the TOR are greater than one because arsenic occurs naturally in air, water, soil and food. For most people, the diet is the largest source of exposure, with concentrations in foods usually ranging from 20 µg/kg to 140 µg/kg. Although, concentrations may be substantially higher in certain seafoods, much of this is in a nontoxic form.

Use of the RfD to predict the potential for adverse non-cancer health effects is a conservative approach. The RfD adopted for this study was derived to protect individuals from developing skin lesions (e.g., hyperpigmentation and keratosis) following continuous long-term (i.e., lifetime) exposures to arsenic. The induction of these skin lesions was apparent only in humans continuously exposed to much higher levels of arsenic than has been estimated in this study, rather than the short intermittent duration of exposure considered in this assessment (60 days/year for Scenario 1 and 14 days/year for Scenario 2). Also, skin lesions associated with arsenic exposures have not been observed in children less than 11 years of age, even when exposed to extremely high concentrations of arsenic in drinking water (US EPA, 1998), which is the highest risk age group identified in this assessment.

In summary, exposure of residents to river sediments in Study Area A results in ER values that are only marginally greater than those received by the 50th percentile TOR and are less than those received by the 95th percentile TOR. Therefore, exposure to arsenic in sediments from Study Area A is not expected to result in a significant incremental risk of non-cancer health effects from chronic exposure.

3.4.3 Cancer

In conducting risk assessments, carcinogens are usually assumed to have a non-threshold type dose response. That is, it is assumed that there is some risk associated with any exposure, no matter how low. Risk characterization of carcinogens involves calculating a Cancer Risk Level (CRL). The CRL is calculated by multiplying the estimated Lifetime Average Daily Dose (LADD) of a chemical by the cancer potency factor (i.e., slope factor, or q*) of that chemical, as outlined below.

$$CRL = LADD \times q^*$$

The CRL defines the predicted excess risk that an individual has of developing cancer in their lifetime as a result of a particular exposure to a substance.

For carcinogens, the toxicological endpoint of interest is the incremental lifetime risk of developing cancer. Since a lifetime is commonly defined as 70 years, the LADD is calculated by amortizing the total lifetime dose over 70 years, even if the exposure is less than a lifetime. The CRL is calculated by multiplying the LADD by the chemical-specific cancer potency factor (q*). The q* is used to define the ability of a chemical to cause cancer in humans. Comparison of the calculated CRL values to cancer risk levels that are *de minimus* (i.e., negligible) is done to determine if the calculated cancer risks are acceptable. Regulatory agencies generally consider CRLs ranging from 1 x 10^{-6} to 1 x 10^{-4} as *de minimus* risk levels.

The estimated exposure to arsenic present in sediments from Study Area A and the calculated CRL based on these exposure estimates for each of the two child receptor scenarios and assuming an average arsenic sediment concentration is given in Table 15.

TABLE 15
Estimated Arsenic Exposure Levels and Associated Cancer Risk Levels (Average)

Receptor Scenario 1	
Lifetime Exposure (Pathways 1 and 2) in µg/kg	209
LADD in µg/kg/day	0.008
Lifetime Cancer Risk	**1E-05**

Receptor Scenario 2	
Lifetime Exposure (Pathways 1 and 2) in µg/kg	69
LADD in µg/kg/day	0.003
Lifetime Cancer Risk	**4E-06**

The lifetime cancer risk for Receptor Scenario 1 is 1 x 10^{-5} and 4 x 10^{-6} for Receptor Scenario 2. These risk estimates are within the range that regulatory authorities generally consider negligible (i.e., 1 x 10^{-4} to 1 x 10^{-6}).

The corresponding lifetime cancer risk estimates based on the maximum detected arsenic concentration in sediments are given in Table 16.

TABLE 16
Estimated Arsenic Exposure Levels and Associated Cancer Risk Levels (Maximum)

Receptor Scenario 1	
Lifetime Exposure (Pathways 1 and 2) in µg/kg	386
LADD in µg/kg/day	0.015
Lifetime Cancer Risk	**2E-05**

Receptor Scenario 2	
Lifetime Exposure (Pathways 1 and 2) in µg/kg	127
LADD in µg/kg/day	0.005
Lifetime Cancer Risk	**8E-06**

The lifetime cancer risks for Receptor Scenario 1 is 2 x 10^{-5} and for Receptor Scenario 2 the risk is 8 x 10^{-6}. These risk estimates are approximately twice those estimated based on the average arsenic concentration, but are well within the range that regulatory authorities consider negligible (i.e., 1 x 10^{-4} to 1 x 10^{-6}).

These risk estimates were compared to the CRLs derived for the 50th percentile TOR (CRL = 5.4 x 10^{-4}) and 95th percentile TOR (CRL = 8.2 x 10^{-4}), as discussed elsewhere (CanTox, 1999).

Total Exposures Using the 50th Percentile TOR:

The increase in the CRL for the 50th percentile TOR because of exposure to arsenic in sediments from Study Area A is very small and does not result in risks exceeding negligible levels. The CRL for the 50th percentile TOR is 5.4 x 10^{-4}. The estimated CRLs based on the average sediment concentration are 1 x 10^{-5} and 4 x 10^{-6} for Receptor Scenarios 1 and 2, respectively. When these risks are added to the CRL calculated for the 50th percentile TOR, the resulting CRL values are not significantly different than the result for the 50th percentile TOR. Based on maximum sediment concentrations, the estimated CRL values are 2 x 10^{-5} and 7 x 10^{-6} for Receptor Scenarios 1 and 2, respectively. The corresponding cumulative CRLs are only marginally greater (approximately four percent) than the CRL for the 50th percentile TOR.

Total Exposures Using the 95th Percentile TOR:

Exposure to arsenic in sediments from Study Area A is expected to increase the CRL for the 95th percentile TOR only marginally. The CRL for the 95th percentile TOR and for the cumulative CRL based on the average sediment concentration are 8×10^{-4}. The cumulative CRLs based on the maximum arsenic sediment concentration are 8×10^{-4} for Receptor Scenarios 1 and 2. The corresponding cumulative CRLs are similar to the CRL for the 95th percentile TOR.

In summary, residents of the Moira River system exposed to sediments in Study Area A are predicted to have CRL values only slightly greater than those received by the 50th or 95th percentile TOR. Therefore, exposure to arsenic in sediments from Study Area A does not significantly increase cancer risks due to arsenic exposure.

3.5 Uncertainty Analysis

In a risk assessment, the doses and benchmarks are estimated from the available information about how exposure might take place and the doses that cause effects. There is always uncertainty associated with these estimations, depending on the quality, quantity and variability associated with the available information. When information is uncertain, it is standard practice in a risk assessment to make assumptions that are biased towards safety, so as to be protective of human health. Every effort is made to ensure that assumptions are specific to the site being evaluated.

There are several layers of safety applied in this Updated PQRA. For instance, the exact amount of time a child spends outside in contact with sediments in Study Area A is uncertain because it varies with the weather, other activities of the child's family, and the child's own preferences. The risk assessment assumed, as a worst case, that a child would spend time in contact with sediments in Study Area A every day for 60 days (Scenario 1) or every day with even more direct contact with the skin for 14 days (Scenario 2). These are conservative scenarios since children would be spending time in other activities as well. Therefore, scenarios 1 and 2 add layers of safety. In this way, if the risk assessment indicates that estimated doses are less than benchmark doses for this "maximally exposed" child, then we can conclude that all children will be protected.

As another example, the quantity of arsenic in sediment in specific areas of Study Area A may be uncertain because the information is based on a limited number of samples at one time period and/or there is considerable variability in concentrations of arsenic between samples in the area. In this case, a layer of safety is added by calculating a dose based on the maximum observed arsenic concentration, even if this was only in one very small area. If the dose based on the maximum arsenic concentration is less than the benchmark dose, then we can be confident that there is no problem across the whole Study Area A.

Use of maximum sediment arsenic concentrations in combination with using the 95th percentile TOR to estimate total exposures adds another layer of safety. It is highly unlikely that residents or users of the river in Study Area A will be exposed to the maximum arsenic sediment concentration *and* also be exposed to the 95th percentile arsenic doses as a TOR.

There is also uncertainty associated with estimating benchmark doses. Benchmark doses are based on toxicity information available from government databases and published scientific literature. The majority of toxicity information comes from the results of experiments with laboratory animals. Some additional information on human health effects is also available for some substances where cases of workplace exposures and associated health effects have been documented. There is some uncertainty in extrapolating from animal studies and workplace case studies to the possible effects that may result from exposure to arsenic in sediments in Study Area A. It is standard practice in a risk assessment to set the benchmark dose at a much lower level than the animal benchmark (typically 100 to 1000 times lower). This is done to ensure that minor exceedances of these benchmark doses will not cause adverse health effects.

This assessment also assumed that individuals would be exposed to inorganic arsenic, which is more toxic than organic forms. Inorganic arsenic in groundwater and surface water can be reduced (methylated) by micro-organisms, albeit to a limited extent. Therefore, it is likely that a portion of the arsenic measured in sediment and water samples along the river system is present in the less toxic organic form. To the extent that some arsenic is present in organic forms, this approach may lead to overestimates of the toxic potency of the arsenic present in the Moira River sediments, and risk estimates may therefore be overstated. The extent of this overestimation cannot be determined based upon the available data.

Because of all of the layers of safety incorporated into the calculation of an ER, values that are at or marginally greater than one do not indicate that adverse effects are occurring or are likely to occur. As explained above, minor exceedances of the benchmark (resulting in ER values slightly above one) are within the layers of safety incorporated into the risk assessment.

4.0 CONCLUSIONS AND RECOMMENDATIONS

This Updated PQRA identifies the specific risks of exposure to arsenic in sediments in Study Area A. It was performed in order to identify whether specific risk management measures were required with respect to exposure to sediments in Study Area A.

No findings in this report should be taken to indicate that adverse health impacts are occurring among river system users.

4.1 Conclusions

Acute Effects:

- Exposure to the range of concentrations of arsenic detected in sediment in Study Area A will not result in adverse health effects after short-term exposure of area residents and other users of the river.

- Exposure to sediments in Study Area A combined with the exposure to arsenic as experienced by the TOR will not result in adverse health effects after short-term exposure of area residents and other users of the river.

Chronic Non-Cancer Effects:

- Exposure to the range of arsenic concentrations in sediments from Study Area A will not result in adverse health effects after long-term exposure of area residents and other users of the river.

- Exposure to sediments in Study Area A combined with the exposure to arsenic as experienced by the TOR will not result in adverse health effects after long-term exposure of area residents and other users of the river.

Cancer Effects:

- The risk of developing cancer due to exposure to the range of arsenic concentrations in sediments from Study Area A is within the range considered negligible or acceptable by regulatory authorities.

- Exposure to sediments in Study Area A combined with the exposure to arsenic as experienced by the TOR will not increase cancer risk significantly; the incremental risk is extremely small.

Based on the results of this investigation, it is concluded that further assessment of the potential health risks associated with arsenic in sediments in Study Area A is not warranted.

4.2 Recommendation

- Based on the results of this investigation, further assessment of the existing arsenic concentrations in sediment is not warranted. **Should conditions change due to a major flood event, or in the event of a significant accidental release of sediments from Young's Creek, follow up sediment sampling would be recommended to confirm that exposure to sediments in study area A continues to represent no significant incremental health risk. Following completion of the final cleanup program for the Deloro Mine Site, including Young's Creek, would also be an appropriate time for follow up sediment sampling.**

The concentration of arsenic in sediment in the follow-up sampling event(s) should be compared with the arsenic concentrations presented in the Updated PQRA and the need for further assessment determined at that time. This will help to ensure that exposure to sediments in Study Area A continues to represent no significant incremental health risk to users of the Moira River.

5.0 REFERENCES

Cantox. 1999. Deloro Village exposure assessment and health risk characterization for arsenic and other metals. Prepared by Cantox Environmental Inc. December, 1999.

Environment Canada. 2000. Annual Meteorological Summary. October 2000.

Golder Associates. 2000. Phase II Moira River Study Impacts of the Former Deloro Mine Site on the Moira River System.

JECFA. 1989. Joint FAO/WHO Expert Committee on Food Additives. Toxicological evaluation of certain food additives and contaminants. Cambridge University Press, 1989: 155-162.

Tseng, W.P. 1977. Effects and dose-response relationships of skin cancer and blackfoot disease with arsenic. Environ. Health Prospect. 19:109-119.

Tseng, W.P., Ghu, H.M., How, S.W., Fong, J.M., Lin, C.S., and Yeh, S. 1968. Prevalence of skin cancer in an endemic area of chronic arsenicism in Taiwan. J. Nat. Cancer Instit. 40(3):453-463.

US EPA. 1998. Integrated Risk Information System (IRIS). United States Environmental Protection Agency.